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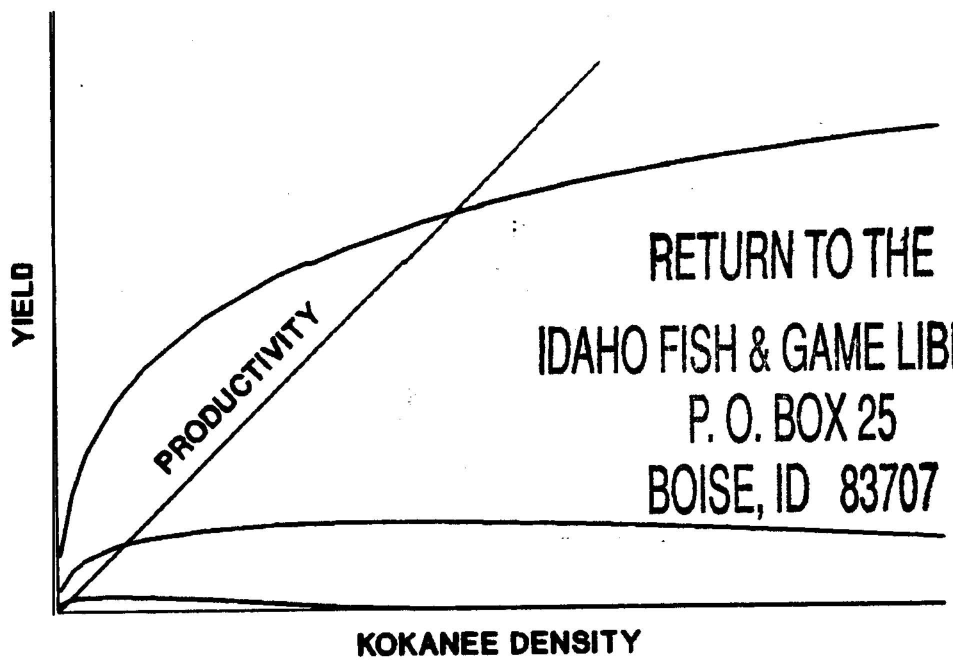
Subproject II
Study No. I
Job Nos. 1, 2, 3

STATUS AND ANALYSIS OF SALMONID FISHERIES
Kokanee Population Dynamics



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JOB PERFORMANCE REPORT

State of: **Idaho**

Name: **Status and Analysis of Salmonid Fisheries**

Project No.: **F-73-R-12**

Title: **Kokanee Population Dynamics**

Subproject No.: **II**

Job 1: **Density-Dependent Growth and Productivity of the Rearing Lake or Reservoir**

Study No.: **I**

Job No.: **I**

Period Covered: **March 1, 1989 to February 28, 1990**

ABSTRACT

We used long-term (up to 12 years) monitoring data on nine kokanee salmon populations to describe density-dependent responses in growth. We found obvious density-dependence in older age classes (age 2+ and 3+) but not in yearling fish. Growth in all age classes was strongly influenced by lake or reservoir productivity. The response in growth was continuous and did not indicate a threshold that could be interpreted as a carrying capacity. Intraspecific competition probably increases with age and probably is not important among age-0+ and 1+ fish, or between those age groups and older fish. The form of the density-dependent response we described for kokanee salmon was different than that often described for sockeye salmon. Mechanisms of population regulation for the two forms probably are different as well. Our empirical models of growth should be useful to managers predicting density-related changes in fisheries of varied productivity. Consistent, long-term data among a number of populations proved to be a powerful method for understanding population responses. This approach should be adopted whenever possible.

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INTRODUCTION

Kokanee salmon, a non-anadromous form of *Oncorhynchus nerka*, are an extremely important resource in Idaho. Populations have been established, or are supported, through hatchery supplementation in most of the oligotrophic lakes and reservoirs of the State. Populations directly support many fisheries but also provide the key forage for trophy salmonid fisheries (Wydoski and Bennett 1981). Together these fisheries represent some of the most important in the State (Reid 1989).

Kokanee salmon typically rear in lakes or reservoirs, foraging on macrozooplankton. Populations often exhibit substantial variation in growth of individuals that can be strongly density-dependent, similar to that reported for juvenile sockeye salmon, the anadromous form of *O. nerka* (Goodlad et al. 1974; Johnson 1965; Rogers 1980; Burgner 1964; Hartman and Burgner 1972). Compensation in growth of sockeye salmon is hypothesized to be the result of exploitive competition for limited food (Goodlad et al. 1974; Kyle et al. 1988; Hartman and Burgner 1972; Johnson 1964, 1965; Brocksen et al. 1970). Because productivity of the rearing environment should influence abundance of food, productivity should also mediate the density-dependent response in growth among sockeye salmon populations (Johnson 1964; Brocksen et al. 1970; Burgner 1987), and presumably among kokanee populations.

The nature of growth compensation in kokanee salmon has not been described. Johnson (1964, 1965) and others (Goodlad et al. 1974; Ricker 1937; McDonald and Hume 1984) provide data that suggest little density-dependent change in growth of some sockeye populations until a threshold density is reached. Our own early observations of Idaho kokanee salmon suggested little density-dependent change in growth at moderate densities, but strong changes in newly established populations or those fluctuating at low densities (Rieman and Bowler 1980). With that information, Rieman and Bowler (1980) hypothesized a complex response in density-dependent growth of kokanee salmon with a threshold (Figure 1) where declines in growth accelerated at high densities.

Because tradeoffs in size and number of kokanee may directly influence the quality of a fishery or forage base, predictions of density-dependent growth should directly influence management goals for population size. For example, management goals for Pend Oreille Lake in Idaho were based on the threshold model. Management assumed that densities could be pushed to the upper threshold with little cost in size of fish and the benefit of increased catch rates.

Because lakes and reservoirs differ substantially in productivity, density-dependent responses in growth and, hence, fishery management goals should also differ among waters. Observations or models for one lake may not correctly guide management in others. Unlike for sockeye, there is no information demonstrating the influence of lake productivity on growth or density-dependent responses of kokanee. Even the hypothetical response for Pend Oreille was an extrapolation from sockeye, and has not been quantified.

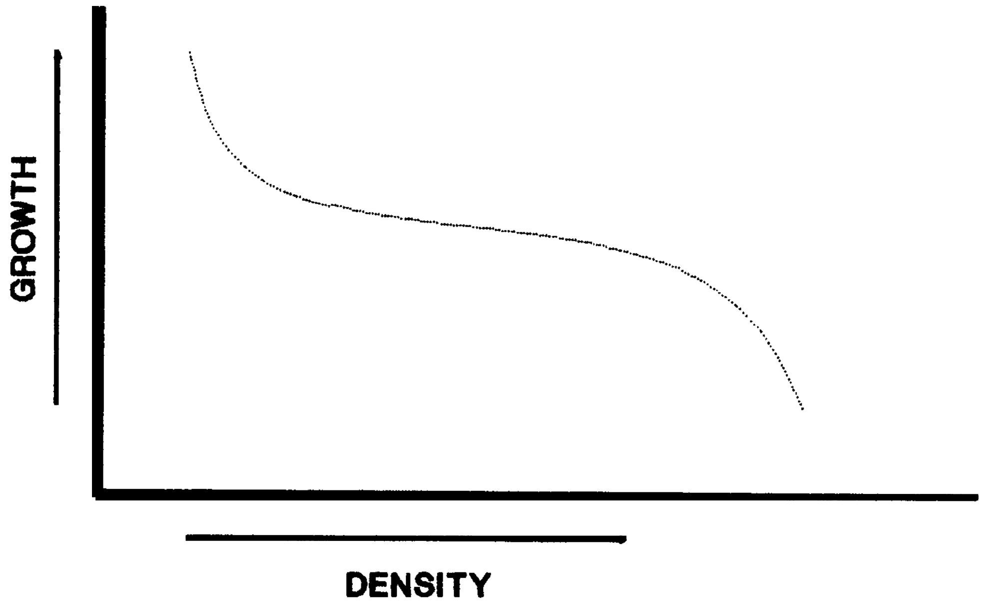

Figure 1. Theoretical densitiy-dependent response in growth of kokanee salmon (after Rieman and Bowler 1980)

Biologists have worked with kokanee populations in Idaho for nearly 50 years. In the last 20 years, the technology for sampling populations improved with the availability of sonar and midwater trawls. Trawl sampling for estimates of population structure and size has been particularly important. Trawling for all ages of kokanee was first developed in Oregon in the early 1970s and adopted in Idaho in 1977. Initial work in Idaho was on Pend Oreille Lake, but sampling expanded to other waters as needs arose. Most work was conducted to address specific management problems with individual populations. However, because the data were collected by a consistent method, and in most cases for at least two years, a sizeable body of information is available.

In this report we use information from the sampling of several kokanee salmon populations to describe relationships of fish growth with density and productivity of the rearing environment. Information from this job is then used with that in Job 2 of this report to develop predictive models of kokanee fisheries.

OBJECTIVES

Objectives of this job were to:

1. Summarize available data on kokanee growth and density and indices of lake productivity for lakes and reservoirs in Idaho and Oregon.

2. Describe relationships between kokanee growth (length-at-age) and fish density and lake productivity. Develop empirical models that will allow managers to predict changes in length-at-age, or to identify optimum densities in individual populations.

METHODS

Productivity

We used available data from several sources to describe six indices of productivity for each lake or reservoir. In most cases, the observations we used were either collected during years of work on the kokanee populations or were estimated from other data collected during that time. Secchi data for Anderson Ranch Reservoir were available only for a period nine years before the kokanee sampling. Whenever several years of data were available, we used a mean for all years. We used Secchi transparency as a mean of weekly or biweekly samples for the period from early May through September. We used estimates of chlorophyll "a" for the same period as Secchi transparency. Chlorophyll was estimated using the spectrophometer method (Slack et al. 1973) from samples pooled either in the upper 10 m of the water column or from the estimated photic zone. We used the maximum estimates of specific conductance available for each lake. Conductance was routinely sampled with a temperature compensating bridge. We used total phosphorous as P. Most phosphorous data was from Milligan et al. (1983), but we developed our own data for Pend Oreille and Priest Lakes. Our estimates of phosphorous in Priest and Pend Oreille were from pooled samples taken in the upper 10 m during spring overturn and were analyzed by the EPA Seattle Laboratory. We estimated a morphoedaphic index (Ryder 1965) for each water by dividing conductance by mean depth in meters. We estimated missing observations by simple regression of the missing parameter on one or more of the others for all available observations. Where more than one significant ($p = 0.05$) regression was available, we used a mean of predicted values. Our last index was a composite of the five preceding parameters. We standardized the five parameters, dividing each by its highest observation among all lakes. For the composite we summed the standardized observations across all parameters for each lake.

Growth, Density, and Productivity

Kokanee were sampled and densities estimated for eight Idaho populations with a midwater trawl. The trawl system was based on that described by Houser and Dunn (1967), differing primarily in trawl dimensions. The Idaho trawl measured 3 m x 3 m at the mouth and was 13.7 m long. Netting in the trawl body graduated in four panels from 32 mm (stretch measure) to 13 mm. Mesh in the cod end measured 6 mm. The net was fished from a double warp with hydrofoils and suppressors to spread the mouth vertically and two doors to spread horizontally. The trawl was towed with an 8.5 m boat powered by a 150 hp diesel engine.

The trawl was fished at 1.3 to 1.5 m/s through the strata of the water column where kokanee were distributed. Depth of the trawl was estimated by a wire angle-depth relationship verified with an echo sounder in a second boat or with a time-depth recorder.

All trawling was done at night during the dark phase (new) moon from July to September. Trawl samples were made in a stepped-oblique fashion. The trawl was dropped to the bottom of the predetermined sampling strata, fished for three to five minutes, raising the bottom of the trawl to a new depth approximating the top of the previous depth, and then repeating the procedure until the full distribution of kokanee had been fished. Fishing time was *constant* within lakes, but modified among lakes depending on relative numbers in the sample. The sampling strata were selected to completely encompass the vertical distribution of kokanee identified by echo sounding (200 khz sounder). Interpretation of echograms was simple for most populations where kokanee were the dominant or only limnetic fish. Young-of-the-year yellow perch were abundant in Anderson Ranch Reservoir, and preliminary trawling of individual strata was necessary to interpret the echograms.

Density of kokanee for each haul was estimated by dividing the catch by the theoretical volume sampled. We assumed 100% efficiency with no net avoidance, and estimated volume sampled as the product of boat speed x mouth area x elapsed time of trawl.

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Initial sampling of each population was random on smaller waters (less than 5,000 hectares) or stratified (by surface area) random on larger waters or systems that had more than one distinct basin. A total of five to thirty trawls, with a minimum of three trawls per areal strata, were made in each water. Trawling locations within a basin or areal strata were selected randomly in the first year of sampling. The original locations were repeated in subsequent years. Total population size was estimated using normal expansions for stratified or simple sampling designs (Scheaffer et al. 1986), based on the lake or reservoir volumes strata-sampled. Density (fish/hectare) was calculated by dividing the total estimate by the area with depth equal to, or greater than, the minimum depth where kokanee were observed.

Growth of kokanee was described by length-at-age. In all trawl samples, kokanee larger than young-of-the-year were measured (total length). We used composite length-frequencies from each population to identify individual age classes and used the mode for each as length at time of sampling. The distributions of age-1+ and age-2+ fish were usually distinct and the modes easily identified. Distributions of age-3+ fish often overlapped with older kokanee. In some samples, aging information was available to partition age classes among individual length classes and was used to interpret the length-frequencies whenever possible. When age-3+ fish could not be clearly distinguished from other cohorts, the observation was eliminated.

Because sampling was conducted from July to late September and because kokanee may grow substantially during that period, we standardized all lengths at sampling to length in late September. To develop the correction, we used data for two populations where samples of each age class were available from June through October on four separate occasions. We divided the length in late September or early October (determined by sample nearest the end of September) by the length in previous months. The correction for each age class in each month was then multiplied by the sample length to standardize the estimate.

To expand our data base to nine populations, we incorporated information collected by the Oregon Department of Fish and Wildlife (Lewis 1974; Lindsay and Lewis 1978) for Odell Lake, Oregon. The Oregon data were collected with a trawl system identical to ours (our boat and trawl were built with specifications from the Oregon boat and trawl). The only difference in sampling in Oregon was that oblique trawl hauls were not used. Rather, trawls were made in individual strata, then processed and the procedure repeated in a new strata until the full vertical distribution was sampled.

We described the relationships between length-at-age and the density of kokanee salmon and water productivity with regression analysis. We analyzed each age class separately, but omitted analysis of age-0+ fish because of extreme variability in length at sampling. Age-O+ lengths appeared to be strongly influenced by emergence or stocking time and stocking size, which we could not accurately describe in all populations. Density was represented either as density of the age class in question or total density of all ages. We performed our analyses using untransformed data, log and squared transformations, and appropriate interaction terms. We report only our "best-fit" results.

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RESULTS

Productivity

Our indices of productivity (Table 1) indicate that waters we studied ranged form ultra-oligotrophic (Payette Lake) to the upper range of oligotrophy. We found significant correlations between several of the indices. The strongest correlations were among summer mean Secchi transparency, chlorophyll "a", MEI, and total phosphorous (Table 2). Conductivity was not strongly correlated with the other indices. We therefore used simple regressions among chlorophyll "a", total phosphorous, MEI, and Secchi transparency (one independent variable at a time) to predict missing observations. When two regressions were possible, we used the mean of the predicted values.

Growth, Density, and Productivity

Corrections for sample length to late September length ranged from 1.46 to 1.07, depending on month of sample and age (Table 3). We generated the most observations complete for corrected length-at-age and density for age-1+ kokanee (47) and the fewest for age-3+ fish (29) (Table 4). Estimated densities ranged about three orders of magnitude among all observations. For populations where individual year classes were sampled in successive age classes, age-3+ density averaged 60% of age-2+ density and age-2+ density averaged 90% of that at age 1+.

Age 1+

Length-at-age 1+ among all lakes was most strongly correlated with Secchi transparency and chlorophyll "a" (Table 5, Figure 2). Length-at-age was positively, although weakly, correlated with density. To remove the influence of productivity we sorted the observations by Secchi transparency. We found slightly negative relationships with density among the populations in the waters of highest and intermediate productivity (Figure 3). Regression models using chlorophyll "a" or Secchi transparency and the log of density at age 1+ or total density (all ages) explained 61% to 63% of the variation in length-at-age (Table 6). Variables representing fish density were significant only when used as total density. Models incorporating density and productivity show the latter to have the strongest influence on length (Figure 3).

Age 2+

We found weak but significant correlations of length-at-age 2+ with log density and several indices of productivity (Table 5). When we sorted the data by relative productivity, a negative relationship between length and log density was evident (Figure 4). The best regression models incorporated log density and

Table 1. Indices of productivity for kokanee salmon lakes and reservoirs in Idaho and Oregon. Data are from Idaho Fish and Game sampling related to this project unless noted in footnote.

Body of Water	Chlorophyll 'A' (ug/l)	Total Phosphorus (uq/l)	Secchi Transparency (M)	Conductance (umhos/cm^2 @ 25°C)	MEI	Index
IDAHO						
Anderson Ranch	4.2[h]	14[f]	3.4[e]	60[f]	2.1	2.41
Coeur d'Alene Lake	4.0	45[f,g]	5.0	80	3.3	2.87
Dworshak Reservoir	4.4[f]	21[f]	4.5[b]	30[f]	0.5	2.18
Payette Lake	<1.0[f]	5.5[h]	9.0	20	0.5	0.78
Pend Oreille Lake	2.0	11	6.5	180	1.1	1.84
Priest Lake	1.5°	4	B.0[d]	50	1.3	1.03
Spirit Lake	5.3[a]	18	3.9	240	22.0	4.13
Upper Priest Lake	2.9[h]	6	6.0	100	8.3	1.98
OREGON						
Odell Lake	3.0	14[h]	7.0	33	0.8	1.52

[a]Soltero and Hall 1984
[b]Mauser et al. 1989
[c]Bellatty 1989
[d]Rieman 1979
[f]Mate 1977 Milligan et al. 1983
[g]Lower values also reported, heavy metal contamination may reduce phosphorus availability
[h]Predicted from regression with secchi, chlorophyll, and/or phosphorus

TABT1.JB1

Table 2. Pearson correlation matrix for six indices of productivity for kokanee salmon lakes and reservoirs in Idaho and Oregon. Significant ($p = 0.05$) correlations are noted by *, sample sizes are shown in parentheses.

	Chlor. 'a'	Total P	Secchi	Conduct.	MET
Chlorophyll 'a'	1.000 (8)				
Total Phosphorus	0.580* (6)	1.000 (9)			
Secchi Transparency	-0.960* (7)	-0.446 (8)	1.000 (10)		
Conductance	0.376 (8)	-0.205 (9)	0.044 (10)	1.000 (10)	
Morphoedaphic Index	0.656* (8)	0.051 (9)	-0.408 (10)	0.528 (11)	1.000 (11)

TABT2.JB1

Table 3. Mean corrections (multiplication factors) for length-at-age sampled prior to late September. Corrections were based on monthly sampling over three years in Pend Oreille Lake (Bowler 1980a) and one year in Coeur d'Alene Lake (Bowler 1980b).

Month	Age 1+	Age 2+	Age 3+
June	1.46	1.14	1.14
July	1.20	1.09	1.11
August	1.11	1.04	1.07

TABT2.JB1

Table 4. Densities (fish/hectare) and September length-at-age[s] for kokanee salmon in nine lakes and reservoirs in Idaho and Oregon.

Water	Year of observation	Length-at-Age 1+	2+	3+	Density-at-Age 1+	2+	3+	Total[b] density
IDAHO								
Anderson Ranch	1986	210	267	-	10	11	4	218
Anderson Ranch	1987	211	234	-	5	111	8	260
Anderson Ranch	1989	-	-	320			5	848
Couer d'Alene	1978	163	205	250	307	129	121	686
Coeur d'Alene	1979	158	195	245	237	186	47	625
Coeur d'Alene	1980	158	185	225	174	202	110	679
Couer d'Alene	1983	144	182	220	198	233	84	672
Coeur d'Alene	1984	150	182	-	121	196	83	473
Coeur d'Alene	1985	161	192	225	89	193	262	972
Coeur d'Alene	1986	162	198	-	268	190	75	758
Coeur d'Alene	1987	161	-	-	247	303	92	1355
Coeur d'Alene	1988	-	-	-	317	395	63	1130
Dworshak	1988	210	261	310	45	4	10	109
Payette	1980	90	156	240	4	36	9	105
Payette	1988	105	175	-	2	6	-	87
Payette	1989	100	-	-	14	-	-	96
Pend Oreille	1977	148	205	235	52	131	29	300
Pend Oreille	1978	148	195	235	31	89	57	258
Pend Oreille	1979	153	215	245	58	75	30	252
Pend Oreille	1980	148	205	255	44	42	46	207
Pend Oreille	1984	158	215	240	67	54	12	249
Pend Oreille	1985	157	221	262	46	55	16	196
Pend Oreille	1986	149	214	233	51	30	24	189
Pend Oreille	1987	142	214	252	35	37	19	266
Pend Oreille	1988	140	205	242	73	23	17	452
Priest	1978	144	213	245	15	14	7	49
Priest	1979	172	208	-	13	2	1	21
Priest	1980	150	-	-	7	-	-	8
Priest	1983	133	-	-	4	-	-	50
Priest	1984	162	-	-	27	2	-	35
Priest	1985	188	245	290	3	4	-	42
Priest	1986	-	263	-	3	1	-	15

TABT2.JB1

Table 4. Continued.

Water	Year of observation	Length-at-Age 1+	2+	3+	Density-at-Age 1+	2+	3+	Total[b] density
Spirit	1981	194	224	260	128	143	161	922
Spirit	1982	204	240	260	364	101	84	1465
Spirit	1983	192	224	260	475	256	94	1075
Spirit	1984	198	229	250	30	280	180	496
Spirit	1985	192	224	256	360	197	129	973
Spirit	1986	192	229	245	501	188	98	816
Spirit	1987	204	229	270	311	605	170	1168
Spirit	1988	204	240	270	393	160	272	950
Upper Priest	1978	150	229	-	3	6	-	90
Upper Priest	1979	139	-	-	28	-	-	81
Upper Priest	1980	138	200	-	25	19	-	169
Upper Priest	1984	133	-	-	6	-	-	148
Upper Priest	1985	150	-	-	15	-	-	28
Upper Priest	1986	161	254	-	7	7	-	54
Upper Priest	1987	155	-	-	21	6	-	-
OREGON								
Odell	1972	164	218	300	37	41	12	124
Odell	1973	185	229	310	10	21	22	105
Odell	1974	160	236	320	11	5	10	36

[a]Sample length was corrected to expected late September length based on observation of monthly growth in two lakes.
[b]Total density includes age 0 fish.

TABT2.JB1

Table 5. Pearson correlation coefficients for kokanee salmon length-at-age with density and indices of productivity in nine lakes and reservoirs in Idaho and Oregon. Significant (p = 0.05) correlations of the expected sign are noted by *.

	Length-at-age		
	1+	2+	3+
(Sample size)	(47)	(39)	(29)
Density at age	0.443	-0.140	-0.246
Total density	0.453	-0.050	-0.134
Log density at age	0.400	-0.358*	-0.409*
Log total density	0.361	-0.223	-0.315*
Morpho-edaphic Index	0.536*	0.274*	-0.017
Total Phosphorus	0.187	0.359	-0.283
Chlorophyll 'a'	0.742*	0.292*	0.189
Secchi transparency	-0.747*	-0.313*	-0.099
Conductivity	0.403*	0.140	-0.322

TABT2.JB1

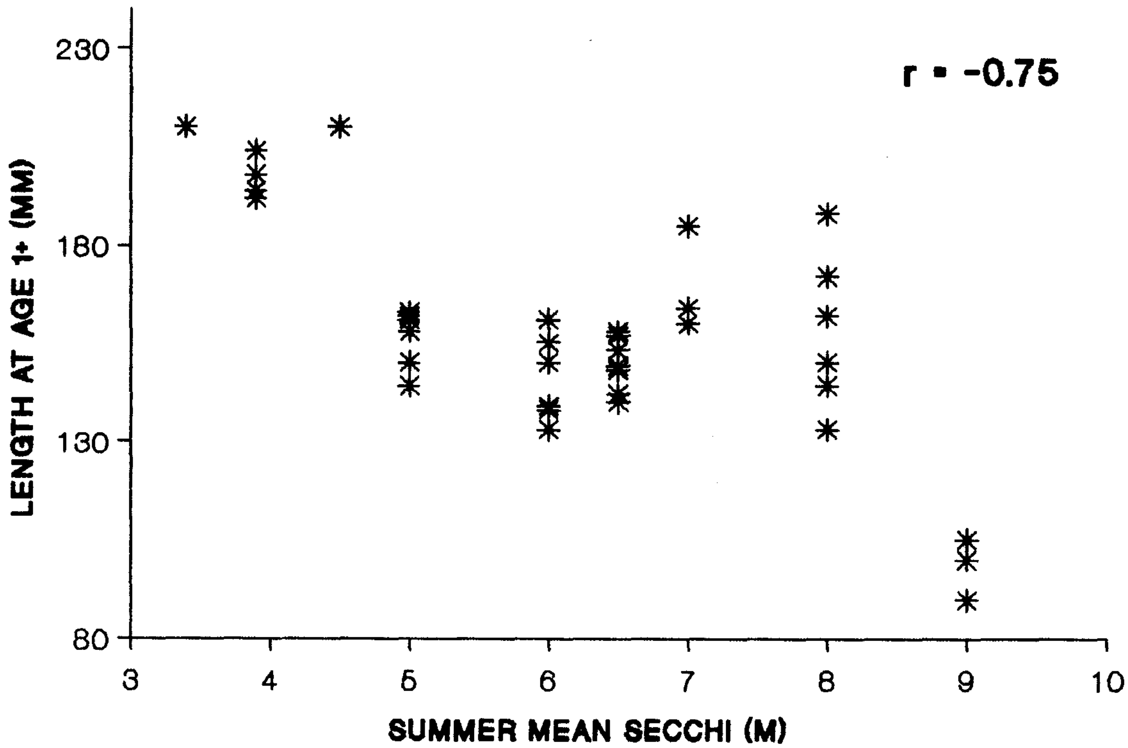

Figure 2. Relationship of length-at-age 1+ between kokanee salmon, and summer mean Secchi transparency in nine lakes and reservoirs in Idaho and Oregon.

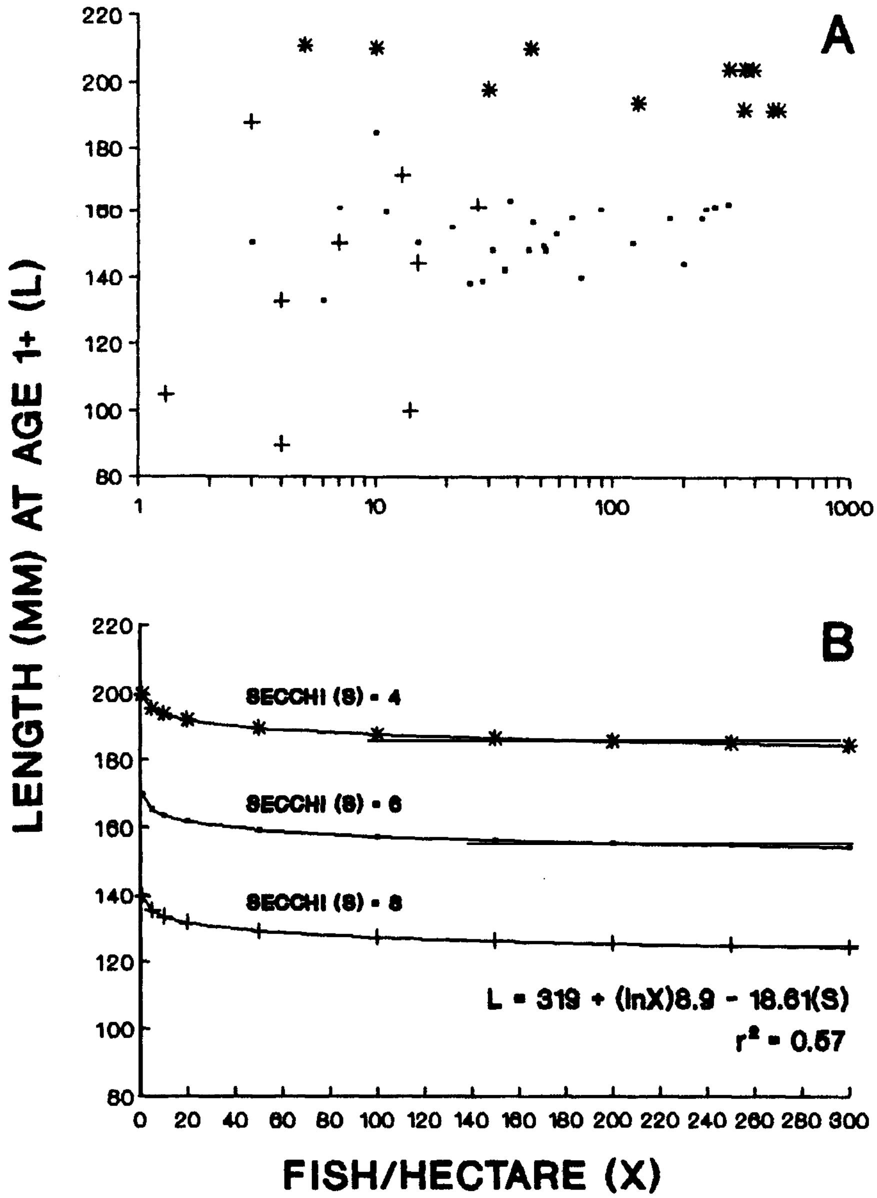

Figure 3. Relationships of length-at-age 1+ for kokanee salmon with density of the age class and Secchi transparency in nine lakes and reservoirs in Idaho and Oregon. 'A' represents observations sorted by Secchi <5m (*); Secchi 5–7m (•); and Secchi >7m (+). 'B' represents the regression model predictions of length with Secchi held constant at three values. Note the difference in scale of the X axis between 'A' and 'B'.

Table 6. Results for regressions of kokanee salmon length-at-age on density and indices of productivity.

Age	Variable	P For coefficients	F Ratio	P for model	R^2	N
1+	Constant	<0.001	29.25	<0.001	0.57	47
	Log Density	0.261				
	Secchi	<0.001				
	Constant	<0.001	37.90	<0.001	0.63	47
	Log Total Density	0.005				
	Secchi	<0.001				
	Constant	<0.001	34.76	<0.001	0.61	47
	Log Total Density	0.011				
	Chlorophyll 'a'	<0.001				
2+	Constant	<0.001	30.00	<0.001	0.63	39
	Log Total Density	<0.001				
	Secchi	<0.001				
	Constant	<0.001	27.61	<0.001	0.61	39
	Log Total Density	<0.001				
	Secchi	<0.001				
3+	Constant	<0.001	8.18	0.002	0.39	29
	Log Density	<0.001				
	Secchi	0.005				
	Constant	<0.000	17.67	<0.001	0.58	29
	Log Density	<0.000				
	Chlorophyll 'a'	<0.000				
	Constant[a]	<0.001	17.66	<0.001	0.66	26
	Log Density	<0.001				
	Secchi	<0.001				
	Constant[a]	<0.001	19.73	<0.001	0.63	26
	Log Density	<0.001				
	Chlorophyll 'a'	<0.001				

[a]Outliers removed

TABT2.JB1

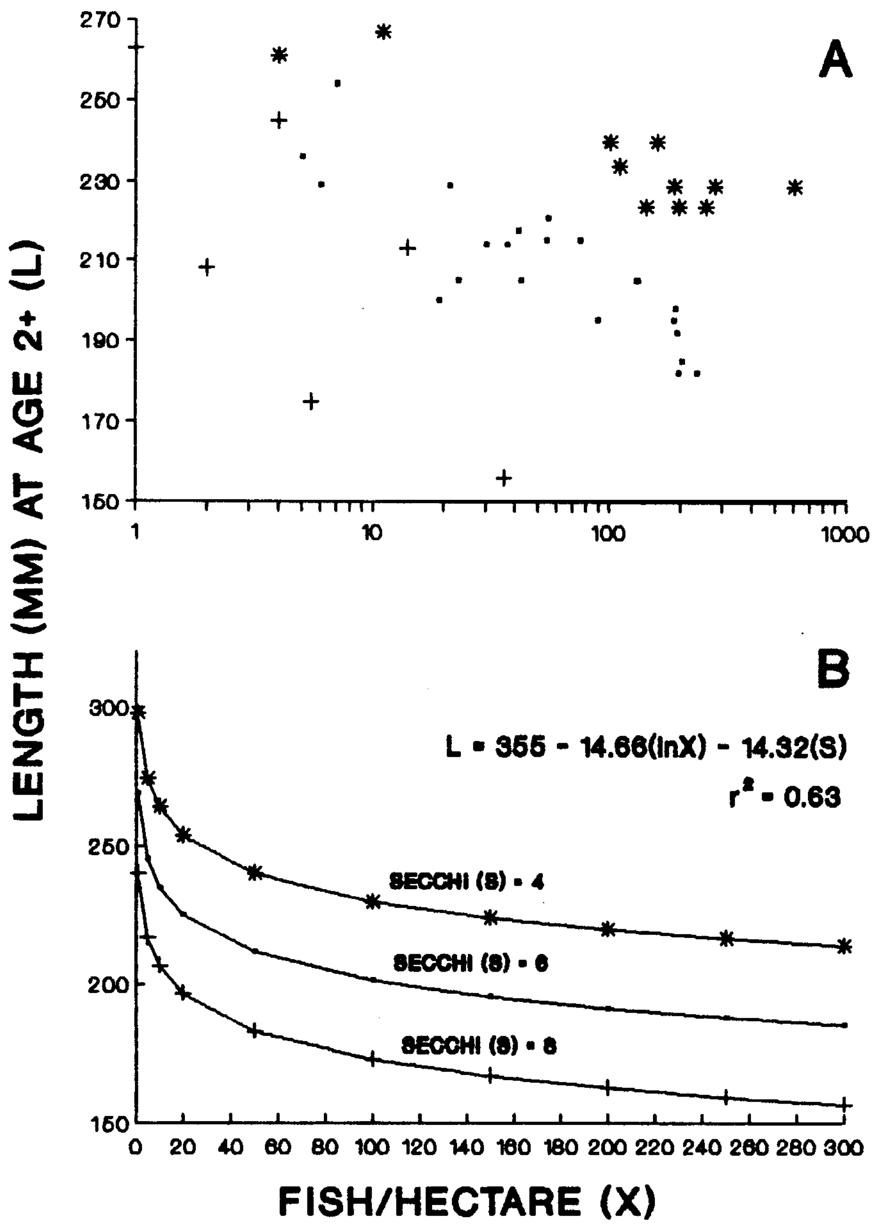

Figure 4. Relationships of length-at-age 2+ for kokanee salmon with density of the age class and Secchi transparency in nine lakes and reservoirs in Idaho and Oregon. 'A' represents observations sorted by Secchi <5m (*); Secchi 5-7m (•); and Secchi >7m (+). 'B' represents the regression model predictions of length with Secchi held constant at three values. Note the difference in scale of the X axis between 'A' and 'B'.

either Secchi transparency or chlorophyll "a" and explained up to 63% of the variation in length (Table 6). Density and productivity were of similar importance in explaining variation in length-at-age 2+ (Figure 4).

Age 3+

Length-at-age 3+ was more strongly, negatively correlated with density than were the other age classes (Table 5). Length was poorly correlated with indices of productivity, or the correlations were opposite in sign of what we anticipated (i.e. length decreased rather than increased with productivity). However, when we sorted the lakes by relative productivity, we again found evidence of density-dependent growth (Figure 5). Three observations in the lakes of intermediate productivity were outliers. All three observations were from Odell Lake, Oregon; the only data not collected in our own sampling program.

Regressions of length on density and Secchi transparency or chlorophyll "a" explained 39% to 57% of the variation in length. Regressions where we eliminated the Odell Lake observations explained up to 66% of the variation in length (Table 6).

DISCUSSION

Our results support a density-dependent response in growth of kokanee that is strongly influenced by productivity. The influence of density on fish growth has been well documented (Boisclair and Leggett 1989), particularly in sockeye (ie. Goodlad et al. 1974; Johnson 1964; Ricker 1937; Burgner 1964, 1987; Hartman and Burgner 1972; Rogers 1980; Kyle et al. 1988) and kokanee salmon (i.e. Maiolie 1988; Lindsay and Lewis 1978; Fraley et al. 1986). The response is commonly thought to be a result of reduced food abundance and size caused by intense size selective predation (Goodlad et al. 1974; Kyle et al. 1988; Brocksen et al. 1970; Trippel et al. 1989; Hartman and Burgner 1972; Boisclair and Leggett 1989). Productivity of the rearing environment can obviously influence the abundance and production of zooplankton and should in turn influence growth of salmon (Brocksen et al. 1970). Johnson (1965) demonstrated a strong relationship between productivity of several lakes and the ultimate size of sockeye smolts. Rieman (1981) reported a similar response with growth of age-0 kokanee and Lewis (1971) found a positive relationship of kokanee size-at-maturity and lake productivity.

Although our relationships of kokanee growth with density and productivity are consistent with theory, the shape of the responses was different than we had anticipated. From our previous observations and information in the literature, we expected to find a threshold where declines in growth accelerated with increasing density (Rieman and Bowler 1980). Our own samples in one population over several years showed no detectable change in growth with roughly two-fold variation in density (Rieman and Bowler 1980). *Johnson* (1964, 1965) provided

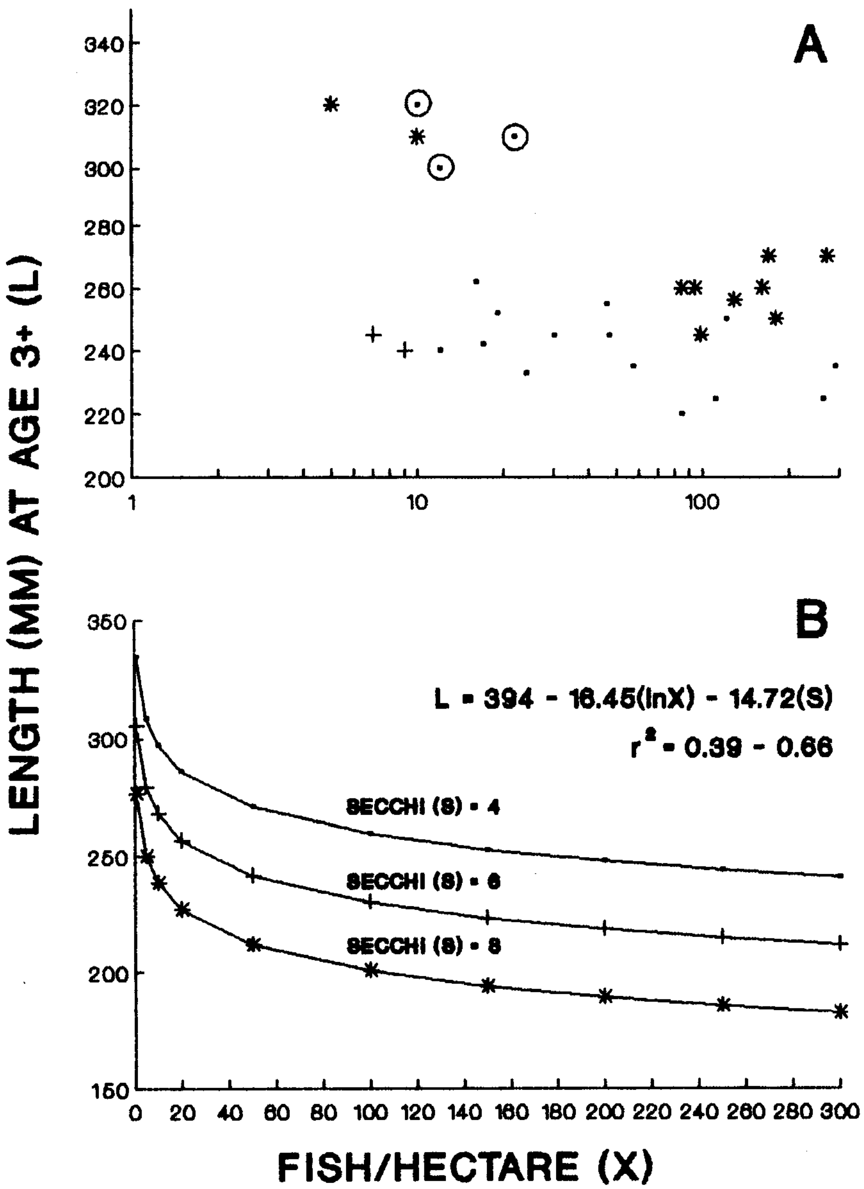

Figure 5. Relationships of length-at-age 3+ for kokanee salmon with density of the age class and Secchi transparency in nine lakes and reservoirs in Idaho and Oregon. 'A' represents observations sorted by Secchi <5m (✱); Secchi 5-7m (•); and Secchi >7m (+). 'B' represents the regression model predictions of length with Secchi held constant at three values. Note the difference in scale of the X axis between 'A' and 'B'. The circled points in 'A' represent outliers and the only data not collected in Idaho. The r^2 in 'B" are values calculated with and without the outliers.

data from several lakes that suggested little change in sockeye growth or zooplankton abundance until fish density reached a relatively high level. Goodlad et al. (1974) and McDonald and Hume (1984) presented information supporting a similar threshold response.

Our results suggest that, at least in older age classes of kokanee, growth follows a continuous decline with density. Changes in growth may be more obvious in rapidly growing or declining populations, particularly those operating at relatively low densities. We probably could not detect changes in our early samples because densities did not fluctuate enough that changes in growth could be detected above other effects and sampling error. Based on our models, a two-fold variation in kokanee density should result in only a 10 to 20 mm change in length-at-age 2+ or age 3+.

We believe that the difference in the response we observed with kokanee and that suggested for sockeye represents an important difference in trophic ecology of the two forms. Sockeye typically rear in a lake for one or two years before migrating to the ocean. Kokanee are resident in lakes during their entire life except for brief periods of spawning and incubation to emergence. Kokanee populations may consist of four or more age classes, with oldest fish often in excess of 200 mm in size. Sockeye populations in lakes rarely exceed 200 mm. The interaction of larger plankton feeding fish with each other and the forage base may be much different than among smaller sizes. As the relative size of predator to prey declines with predator growth, foraging and growth efficiencies should also decline (Zaret 1980). That effect is probably aggravated by size-selective foraging, and a shift from large to small prey forms through cropping (Zaret 1980). Intraspecific competition for a zooplankton food base should be more severe among large than small fish and, thus, more apparent at low densities of kokanee than sockeye.

We suggest that intraspecific competition in kokanee i- more important within, rather than among, age classes. The influence of density on growth was much less obvious in our data for age-1+ kokanee than older -ge classes. In earlier work, we also found a positive relationship of length to age 1 (ie. growth of young-of-the-year) with lake productivity among several populations with large differences in density (Rieman 1981). Differences in foraging efficiency with size may be important, but age classes may also segregate spacially and through food selection. We often observed young kokanee in clumped distributions with age-0+ and age-1+ fish at opposite ends o a lake. Older age classes were distributed more uniformly: Similar observations have been reported for sockeye populations with multiple year classes (Hartman and Burgner 1972) and for yellow perch (Keast 1977). In earlier, work we -lso described a divergence in food habits among age classes of kokanee that were accentuated with distance in age (Rieman 1980; Rieman 1981). Hoag (1972) resorted a similar divergence among age-0 and age-1 sockeye.

The density-dependent response in growth of young kokanee ight be similar to that suggested for sockeye if kokanee densities were as igh. Johnson's (1965) data suggested that density-dependent growth in sockeye Became important at 1,000 to 5,000 fish/hectare. In our samples, age-1+ kokane ranged from 0 to 500 fish/hectare. Age-0+ densities were not reported here bu were typically

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10% to 100% higher than age 1+. Even in our strongest populations, total kokanee did not exceed 1,500 fish/hectare. Densities similar to those that produce a substantial decline in growth of age-0 or -1 sockeye are probably rare.

If density-dependent growth in kokanee is unimportant in the youngest age classes, population regulation may occur through different mechanisms than in other fishes. Density-dependent responses in the youngest age classes are commonly thought to be responsible for regulation of most populations (Cushing and Harris 1973; Saila 1987). Size-biased mortality mediated by density-dependent growth is a commonly cited mechanism, and is supported from work with sockeye (Johnson 1965; Hyatt and Stockner 1985). If kokanee do not commonly reach densities where growth of young fish is strongly density-dependent, another mechanism must be important. Fecundity is strongly dependent on size of adult females (Collins 1971). Egg size has also been shown dependent on female size in sockeye and in other salmon (Taylor 1980; Bradford and Peterman 1987; Murray et al. 1989). Smaller females tend to produce smaller eggs and resulting alevins and fry which may suffer higher mortality (West and Larkin 1987; Murray et al. 1989). If the number and quality of kokanee eggs, embryos, or alevins and their ultimate survival is strongly influenced by adult size, density-dependent growth in older age classes of kokanee could be a primary force regulating population size.

Limitations of the Analysis

Our best models explained 50% to 60% of the variation in length-at-age. Undoubtedly part of the remaining variation is the result of sampling and estimation errors or inconsistencies. Density of age-3+ kokanee, for example, can be strongly influenced by fishing mortality that occurs primarily in that year of life. Because our sampling was done during late summer, populations under heavy fishing pressure would have declined substantially just prior to sampling, while those with little pressure would have been relatively stable. Estimated density at sampling time might not accurately represent the density influencing growth. We also found when we removed the observations from Odell Lake (the only data not collected in our own sampling program) the models of length-at-age 3+ improved substantially.

In addition to any error in the data, we believe that other factors must influence growth. Goodlad et al. (1974) and Burgner (1987) suggested lake temperature regimes could influence growth of sockeye. We do not have seasonal temperature information on all lakes or reservoirs, but because the lakes vary in surface elevation, size, depth, and local climate, we expect that temperatures and thermal stratification could be very different. We believe stocks of kokanee also differ in growth potential. Kokanee are often differentiated as early spawning (August to October) or late spawning (October to January), and both varieties exist among the populations we sampled. If emergence time varies, different stocks may experience different first growing seasons. Early spawning adults may also move out of the lake during a period of peak forage abundance or divert energy to maturation earlier in the season than late spawning stocks and, thus, experience a shorter last growing season. Fish and invertebrate

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communities probably also are important. Keast (1977) thought the abundance of other fish was the primary factor influencing growth of perch among several study populations. Mysids are thought to compete with juvenile kokanee (Rieman and Falter 1981; Martinez 1986; Morgan et al. 1978), but to also provide an alternate forage for older-age kokanee. Mysids have been linked to substantially higher growth rates for some kokanee (Northcote 1972; Rieman and Bowler 1980). We have not described the fish and invertebrate communities of our study lakes, but we do recognize some important differences. Mysis relicta is abundant in three of the lakes (Priest, Upper Priest, and Pend Oreille), and yellow perch, lake whitefish, and/or pygmy whitefish were common in trawl samples of several, but not all, lakes.

Summary and Conclusions

We did not attempt to incorporate other variables in our models because our number of observations and, thus, degrees of freedom are limited, but also because observations of some variables are not complete. Our hypothesis of interest was that fish density and lake productivity were the primary variables influencing growth of kokanee. Our results provide strong support.

We suggest that density-dependent growth in kokanee is different than in sockeye, and that a "threshold" effect probably does not occur in older age classes. That response has important implications for management. Managers should anticipate that large changes in growth will be most evident in populations exhibiting rapid growth in number, or those fluctuating around relatively low densities. Conversely, managers should expect relatively small changes in growth with populations operating at high densities without major changes in those densities. Attempts to manage for "large kokanee" might necessarily push populations to dangerously low levels. Because populations operating at minimum densities and maximum growth lack much compensatory reserve (e.g. Saila 1987), those populations could be vulnerable to catastrophic events, overexploitation, or depensatory mortalities, such as predation, that could result in collapse.

Our models should allow managers to approximate anticipated growth for individual lakes, or perhaps to examine growth and approximate density. Our results might also be linked to other models of size-related catchability or fecundity to examine tradeoffs in potential yield (to anglers) or egg production (for hatchery programs) with management of population size.

Other variables might be incorporated in our models to refine the predictions and gain further insight into the relevant biological processes, especially as more lakes and observations are added to the data base. A regional sampling program to develop consistent data for populations among several states and provinces could be particularly powerful. An attempt to standardize sampling among research and management agencies working on kokanee would be necessary. We think the collection of relatively simple data on many populations can be more useful than the intensive study of only a few populations. Our own intensive work on population processes and trophic ecology in a few lakes (i.e. Rieman and

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Bowler 1980) produced a much different conclusion about density-dependent growth than the results of this more extensive (but limited in detail) monitoring through time. Intensive and relatively difficult limnological work incorporating data on zooplankton dynamics and predator cropping in one or two lakes (i.e. Rieman and Bowler 1980) told us less about potential carrying capacity and the effects of fish density on growth than did basic population data and simple indices of lake productivity for nine lakes.

RECOMMENDATIONS

1) Managers should exercise caution for populations with fish approaching the sizes (275 to 325 mm) indicative of low densities. Management goals for fish size should consider lake productivity. Growth and, thus, the ultimate size of kokanee is strongly related to density and lake or reservoir productivity. Large changes in growth should be more obvious in populations operating at low densities. Those populations could be particularly vulnerable to catastrophic events or depensatory mortalities and may risk collapse.

2) Kokanee sampling conducted in the future should be collected in a format consistent with the data summarized here. Consistent, long-term data among a number of populations proved to be a powerful method for understanding population responses. Coordinated research and management programs designed to develop consistent long-term data on kokanee should be pursued both within the State and among surrounding states and provinces. This approach should be the most efficient means of addressing other fisheries problems and should be adopted whenever possible. This data base should be updated and analyzed on a regular basis.

ACKNOWLEDGMENTS

The data summarized in this report are the result of work by many people, including the following: Bert Bowler, Vern Ellis, Pete Hassemer, Bruce Reininger, Larry La Bolle, Ed Bowles, Tim Cochnauer, Melo Maiolie, Gregg Mauser, Ned Horner, Fred Partridge, Don Anderson, Dick Scully, and Scott Grunder. Howard Brown and Gary Ady helped with transport of the trawl boats.

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JOB PERFORMANCE REPORT

State of: **Idaho**

Name: **Status and Analysis of Salmonid Fisheries**

Project No.: **F-73-R-12**

Title: **Kokanee Population Dynamics**

Subproject No.: **II**

Job 2: **Influence of Density on Potential Yield: Prediction of Stocking Rates**

Study No.: **II**

Job No.: **II**

Period Covered: **March 1, 1989 to February 28, 1990**

ABSTRACT

We used kokanee lengths from samples in the trawl and angler catch to estimate relative vulnerability to anglers by fish size. We linked regression models of vulnerability to previous models of density-dependent growth to predict relative changes in vulnerability, catch rate, and yield with varied kokanee density, age-at-maturity, and lake productivity.

Kokanee became vulnerable to anglers at about 180 mm, and vulnerability increased with length. Predicted vulnerability increased in exponential fashion with declining density of fish. Exploitation may increase dramatically in populations with densities of age-3+ fish less than 10 to 20 per hectare and could result in the collapse of the fishery. Size of fish for a given productivity can be used as an index of fish density, and unusually large fish should serve as a danger signal for managers.

Predicted catch rates and yields increased at a declining rate with fish density. In low productivity waters, yields may actually decline with higher densities. The quality of a kokanee fishery will not increase proportionally with stocking rate or density. Optimum densities are probably lower than previously anticipated. We see little benefit in densities exceeding 40 to 50 age-3+ fish per hectare in most lakes, or 20 fish per hectare in unproductive lakes. Stocking rates of 100 to 500 fry per hectare should be adequate for most Idaho waters. Because of uncertainty in survival, stocking programs should progress in experimental fashion.

Age-at-maturity had **a** large influence on predicted yield and was more important than fish density. Further work defining the tradeoffs between density and age-at-maturity or the mechanisms influencing age-at-maturity in kokanee will be useful.

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When we varied lake productivity over the range observed in our data (summer mean Secchi 4 to 8 m), we produced a 13-fold difference in predicted yields. Productivity of individual lakes and reservoirs must be considered to develop realistic management goals. Simple indices of productivity, including Secchi transparency, total phosphorus, and chlorophyll will provide the most useful data for evaluating the relative potential of Idaho kokanee waters.

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INTRODUCTION

Growth of kokanee salmon is influenced by fish density and productivity of the rearing environment (Job 1 this report). Differences or changes in growth can produce important differences and changes in the fisheries. Anglers often show a strong preference for size of fish. Large fish are usually preferred, but the quality of the fishery ultimately results from tradeoffs between numbers and size (Anderson 1975). Catchability of fish or invertebrates may be influenced by size of the individual (Ricker 1975; Miller 1989; Beamesderfer and Rieman 1988). Usually, larger fish are more vulnerable to fishing or angling. With kokanee, most fish in the catch are typically of the oldest age class, even though numbers of sub-adults may be much higher.

As density of kokanee increases and size of fish declines, fishing success and yield should increase, but at a decreasing rate. At some point, the fishery may even decline. The fishery in Coeur d'Alene Lake in northern Idaho showed a continuous decline in size of fish from first introduction in the 1950s to the late 1970s. During that period, total catch increased dramatically from tens of thousands to hundreds of thousands of fish (Rieman and Ward 1981; Rieman and La Bolle 1980). Despite the dramatic increase in numbers harvested, total yield by weight in 1980 and 1981 was similar to that observed in the 1960s. Trawling started in 1978 showed that the population remained at high densities while growth continued to decline into the 1980s. Catch rates and angler effort also declined despite the very high densities of fish. Managers concluded that Coeur d'Alene Lake fish were maturing before they became fully vulnerable to the fishery. "Stunting" is a common problem in fishery management, and it is clear that there can be too many kokanee.

Many Idaho kokanee fisheries rely on hatchery releases for some or all of the recruitment. Hatchery production provides the flexibility to manipulate fish density. If the quality of the fishery is dependent on the density of fish, then the ratio of fishery benefits to cost will vary with stocking rates. Tradeoffs should be substantial and will probably vary with productivity of the rearing environment. The optimum stocking rate may differ among lakes.

In the past, kokanee stocking rates have had little quantitative basis. Enhancement goals for Pend Oreille Lake, Idaho, were based on the historic catches, estimates of historic population size, and estimates of carrying capacity. Previous work suggested little density-dependent tradeoff below the target population size (Job 1 this report; Rieman and Bowler 1980). Other stocking requests have been based on the Pend Oreille Lake goals (i.e. Scully and Anderson 1989), or more simply on past tradition or available numbers. Managers have not typically considered differences among lakes when selecting stocking densities. In some fisheries, managers have correlated stocking rates with harvest and catch rates (Bill Wiltzius, Colorado Division of Wildlife, unpublished manuscript; Domrose 1987), but have not quantified an optimum stocking density. Management goals have included fish size, catch rate, or harvest (Graham et al. 1980; Moore 1986), but have lacked a quantitative basis for determining fisheries benefits in relation to management costs or risks.

The response of a fishery to changing density and lake productivity is predictable with existing data. In this report, we use length-frequencies of kokanee in angler and trawl catches to describe relative vulnerability of varied sizes of kokanee. We then link the empirical models of vulnerability and growth (Job 1 this report) to predict differences in fisheries expected with varied kokanee density and lake productivity. We assume that the relative catch rate or the relative yield (numbers or weight of fish taken by an individual angler with a constant unit of effort) represent useful measures of fishery benefits.

The best approach to understand fishery responses will be to measure them directly under varying density and lake productivity. With enough information, an empirical model should provide better predictions than our mechanistic approach described above. In this report, we also summarize available creel and population data to determine whether the empirical models are possible and to compare observed responses with our predictions.

Our results should help fishery managers develop realistic goals for kokanee fisheries. Our results should also help mangers anticipate the relative changes in a fishery given changes in stocking rates or other actions that will change fish density.

OBJECTIVES

Data on a number of kokanee fisheries are available from creel census and trawl sampling. Data have been collected through both research and routine management. In this job, we used the existing data base to address the following objectives:

1. Describe size related vulnerability of kokanee to anglers.
2. Link models of vulnerability to previous models of density-dependent growth (Job 1 this report), and predict responses in kokanee fisheries to changes in fish density and lake productivity.
3. Compare observed responses in kokanee fisheries with our model predictions.
4. Estimate appropriate stocking densities for hatchery supported kokanee fisheries.

METHODS

Vulnerability

We described size-dependent vulnerability to angling by relating length-frequencies in angler catches to length-frequencies in trawl samples. Lengths (total length) in angler catches were recorded in routine creel census. Lengths in trawl catches were recorded during annual population sampling with a midwater trawl described in Job 1 of this report. All fish were recorded in 10 mm length groups, with length listed as the lower bound of the length interval. We limited the frequency distributions in both samples to fish larger than 170 mm, the smallest group observed in any angler catch. We used only data where both samples were collected within the same 4-week period. Typically, trawling was conducted in a 2- to 5-day period within a 2- or 4-week creel census interval.

We calculated relative vulnerability by dividing the proportion in each classe considered in the catch by the same proportion in the trawl. We assumed that trawl samples accurately reflect the size composition of the population. The trawl gear could produce size-biased samples by selecting against large fish that avoid the gear better than small fish. We do not think bias is large because population estimates of older age classes have been similar to escapement estimates and because estimates of mortality among age classes are consistent with observed exploitation rates (Bowles et al. 1989). We calculated a relative vulnerability (V_R) between size classes.

We standardized the relative vulnerability of each size class against that for 230 mm fish arbitrarily given a value of one. We used 230 mm as the standard because it was the smallest length group found in all catch samples.

The resulting index represents a standardized vulnerability relative among all size classes. A value of zero means that no fish were caught. A value of two means that, given equal densities, twice as many fish will be caught by a unit of effort than for a size class with a value of one.

We used linear regressions to describe relationships between relative vulnerability and length.

Predicted Fishery Responses

To predict the influence of fish density on vulnerability, yield, and catch rates we linked regression models of growth against fish density and productivity (Job 1 this report) to our regression models of vulnerability (Figure 1, Table 1). We assumed that the catch rate in a fishery is directly proportional to density x vulnerability. We further assumed that yield to the angler is equal to catch rate x fish weight. We predicted weight from length based on standard regressions (Ricker 1975) derived from trawl data in four lakes. Our results do not represent actual catch rates or yields, but relative values without unit. Results can only be used to examine the relative change in yield or catch rate anticipated with changes in fish density or lake productivity.

We used a computer spread sheet to repeat calculations of relative yield and catch rate for fish densities of one to several hundred fish per hectare. We predicted responses at three levels of productivity represented by Secchi depths of 4, 6, and 8 m (see Job 1 this report). We ran an initial set of simulations for both age-2+ and age-3+ fish.

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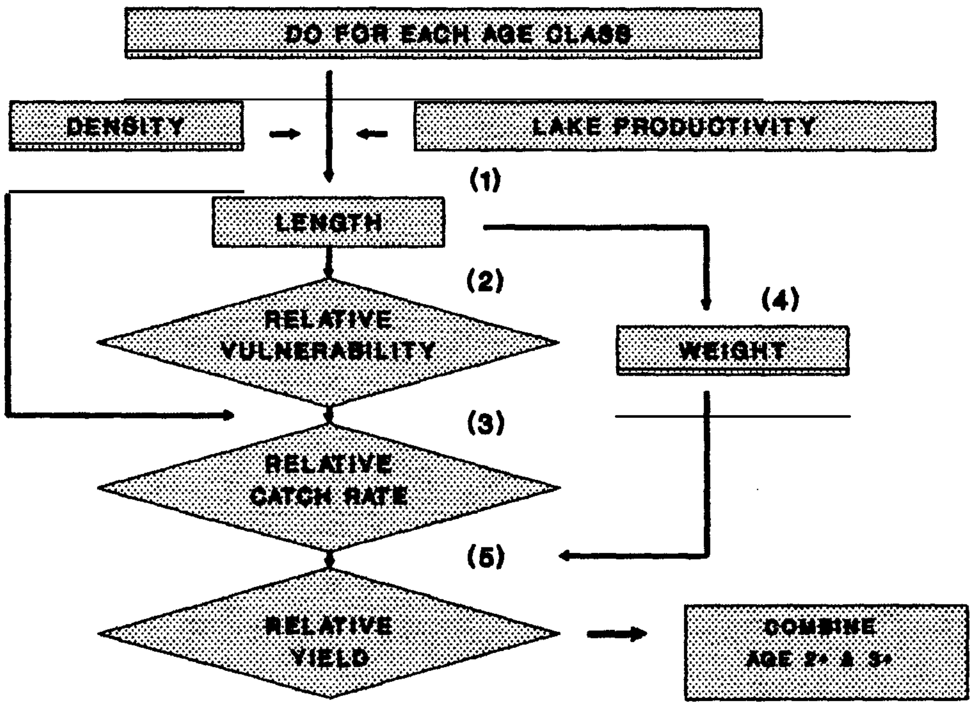

Figure 1. Flow chart for model used to predict relative vulnerability to anglers, catch rate, and yield for kokanee at varying densities and in lakes or reservoirs of varying productivity. Numbers represent equations use in the model and summarized in Table 1.

Table 1. Equations for models used to predict relative vulnerability, catch rate, and yield from kokanee density and lake productivity. A flow chart of the model and equations is shown in Figure 1. L = length (mm); x = density (fish/hectare); s = Secchi (m); V_r, = relative vulnerability; C_r, = relative CPUE; W = weight (g); and Y_r, = relative yield.

(1)[a]	Age 2+	$L = 355 - 14.66(\ln x) - 14.32(s)$
	Age 3+	$L = 394 - 16.45(\ln x) - 14.72(s)$
(2)		$V_r = 0.023(\ln L) - 4.302$
(3)		$C_r = V_r(X)$
(4)[b]		$W \quad 1.21 \bullet 10^{-6}(L^{3.35})$
(5)		$Y^r = C_r(W)$

[a]from Job 1, this report.
[b]unpublished length-weight relationship for Pend Oreille Lake.

TABT1.JB2

In reality, kokanee from several age groups will contribute to the catch depending on their size and vulnerability. Age of maturation will have an important influence on the ultimate size of fish available to anglers and, thus, the relative yield. To predict the effect of changing age-at-maturity, we combined our models of yield for age-2+ and age-3+ fish. We assumed average survival between age 2+ and age 3+, when all fish mature at age 4, to be equal to the mean survival estimated for all lakes (see stocking rates below). To simulate fish maturing earlier, we imposed additional mortality between age 2+ and age 3+. The additional mortality was equal to the proportion maturing at age 3 (i.e. age-2+ fish maturing at age 3 will not survive to age 3+).

We examined the uncertainty in our yield predictions caused by uncertainty in the relationship between vulnerability and length. We repeated our simulations with a range of coefficients for the vulnerability-length model. We used our regression model coefficients from the pooled data for a base simulation. We repeated the simulations with an upper and then lower value for the slope, an upper value of the intercept and, finally, upper values for both parameters combined. The values produced a range of vulnerability responses similar to those observed in our data.

Empirical Responses

We used actual creel data for populations sampled by trawl to examine relationships of catch rate (kokanee/angler hour), yield to the angler (kg/angler hour), or effort (total angler hours) against fish density, productivity (Secchi depth), and fish length (September length-at-age 3+). We assumed effort to be a measure of quality in the fishery. We hypothesized that effort among lakes should respond directly to changing catch rate or yield. If that is true, response in effort should then be similar to that predicted for catch rate and yield with our previous models. Because catch rate and yield in our models were dependent on fish size, we also anticipated that empirical catch rates and yields should be related to fish density and length.

Stocking Rates

We summarized survival estimates for wild and hatchery-released kokanee to help managers determine stocking rates for hatchery-supported fisheries. We used the responses from the previous simulations to identify densities beyond which little benefit would be expected in the fishery. Stocking rates can be approximated as the density of fry necessary to produce the desired density given anticipated survivals.

TEXT.JB2

RESULTS

Vulnerability

We found enough data to estimate vulnerability for five occasions in two fisheries (Table 2). Estimates of relative vulnerability increased with size of fish in all cases (Figure 2). The rate of increase varied among the observations. Log-linear regression models fit the data well, with estimated slopes ranging from 0.013 to 0.064 (Table 3). We calculated intercepts with the X axis (length where vulnerability = 0) *ranging* from about 170 mm to 220 mm. Models of vulnerability used in the uncertainty analysis of yield predictions (Table 4) produced responses similar to that observed in our data (Figure 2).

Predicted Responses

Predicted vulnerability declined in exponential form with increasing fish density (Figure 3). Productivity influenced the magnitude of the response but not the form or rate of change.

Predictions of relative yield for age-3+ kokanee increased at a declining rate with *increasing* density (Figure 4). The rate of decline was strongly influenced by lake productivity. With the lowest productivity (Secchi = 8), yield declined dramatically at densities above about 20 fish/hectare. Productivity also strongly influenced the magnitude of yield. Peak yield ranged about 30-fold among the three levels of Secchi transparency, and yield at 20 fish/hectare ranged about 15-fold. Predictions of relative catch rates followed a similar pattern, though peak catch rates occurred at higher densities than peak yields (Figure 5).

Predictions of yield for age-2+ fish followed patterns like those for age-3+ fish with two important exceptions; the overall magnitude of yield was lower (age 2+ peaks were about 15% of age 3+), and the decline in yield at higher densities was more pronounced (Figure 6). Combined yields for age 2+ and age 3+ varied substantially with age-at-maturity. A change in mean age-at-maturity from 3.5 to 4 years (i.e. 50% of age-2+ and 100% of age-3+ fish mature) produced a 1.8-fold increase in total yield (Figure 7).

Uncertainty in the vulnerability coefficients influenced predictions of yield (Figure 8). *Changing* the slope altered the magnitude of predicted yield, but did not dramatically change the form of the response. Changes in the X intercept (length where vulnerability = 0) had an important influence on both the magnitude and shape of the response. *Increasing* the intercept produced a peak in yield at relatively low densities. The result was similar to the base simulation at low productivity.

Table 2. Sampled angler catch and trawl catch data used to estimate the index of relative vulnerability with 10 mm length group.

Length group	Angler catch	Trawl catch	Vulnerability index	Source
Pend Oreille 1977				Bowler and Ellis 1978 Raw Data Files
160	0	0	--	
170	0	0	--	
180	0	3	--	
190	10	86	.08	
200	20	152	.09	
210	48	136	.25	
220	28	20	.98	
230	40	28	1.00	
240	59	20	2.07	
250	31	8	2.71	
260	24	3	5.60	
270	14	2	4.90	
280	4	0	--	
290	0	0	--	
Pend Oreille 1978				Ellis and Bowler 1979 Raw Data Files
160	0	0	--	
170	0	0	--	
180	2	18	.06	
190	6	87	.04	
200	17	33	.30	
210	26	53	.29	
220	32	42	.44	
230	60	35	1.00	
240	133	25	3.10	
250	84	18	2.72	
260	47	3	9.14	
270	11	1	6.42	
280	1	2	0.29	
290	0	0	--	
Pend Oreille 1979				Ellis and Bowler 1980 Raw Data Files
160	2	21	.04	
170	2	3	.28	
180	2	2	.41	
190	24	29	.34	
200	41	59	.29	
210	63	73	.36	
220	31	26	.49	

TABT1.JB2

Table 2. Continued.

Length Group	Angler catch	Trawl catch	Vulnerability index	Source
230	46	19	1.00	
240	102	29	1.45	
250	123	18	2.82	
260	73	10	3.02	
270	33	4	3.41	
280	9	1	3.72	
290	0	0	--	
Pend Oreille 1980				Ellis and Bowler 1981 Raw Data Files
160	0	0	--	
170	0	0	--	
180	1	0	--	
190	3	26	.13	
200	16	51	.36	
210	33	35	1.08	
220	43	42	1.18	
230	20	23	1.00	
240	47	18	3.00	
250	105	18	6.71	
260	156	11	16.31	
270	108	0	--	
280	43	2	--	
290	0	0	--	
Spirit Lake 1981				Ellis et al. 1982
160	0	3	--	
170	0	17	--	
180	0	22	--	
190	0	1	--	
200	0	2	--	
210	2	15	--	
220	0	15	--	
230	1	10	1.00	
240	1	7	1.43	
250	17	15	11.33	
260	27	23	11.74	
270	12	6	20.00	
280	1	0	--	
290	0	0	--	

TABT1.JB2

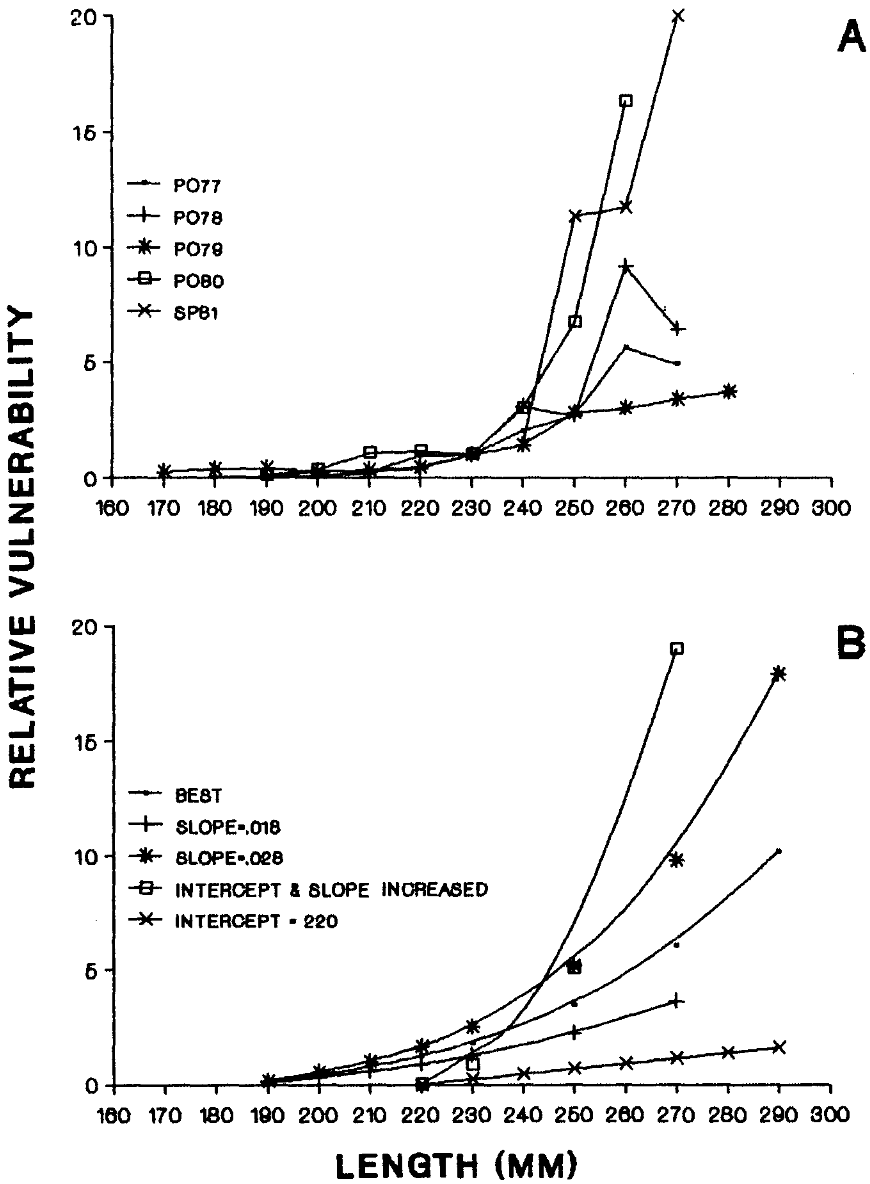

Figure 2. Relationships of relative vulnerability to anglers and length for kokanee in two lakes. A represents the actual estimates from the data in individual length groups. B represents the regressions used to predict vulnerability in our model. Coefficients for the regressions are summarized in Table 4.

Table 3. Regression models fit to the vulnerability index against length data available for five occasions on two lakes.

Lake	Year	Regression model	R^2
Spirit Lake	1981	In (vulnerability + 1) = - 14.067 + 0.064 (length	0.93
Pend Oreille	1977	In (vulnerability + 1) = - 4.325 + 0.023 (length)	0.94
Pend Oreille	1978	In (vulnerability + 1) = - 4.925 + 0.026 (length)	0.88
Pend Oreille	1979	In (vulnerability + 1) = - 2.185 + 0.013 (length)	0.86
Pend Oreille	1980	In (vulnerability + 1) = - 6.829 + 0.035 (length)	0.87
Pooled[a]		In (vulnerability + 1) = - 4.302 + 0.023 (length)	0.71

[a]all lakes, all years

TABT1.JB2

Table 4. Parameters for models[a] of relative vulnerability (y) and length (L) used to examine uncertainty in predictions of relative yield.

	Slope (b)	Intercept with X axis (I)
Best Fit	0.023	185
Alternative Models	0.028	185
	0.018	185
	0.023	220
	0.060	220

[a]predictive model $y = e[(L-I)(b) - 0.0006] - 1$

TABT1.JB2

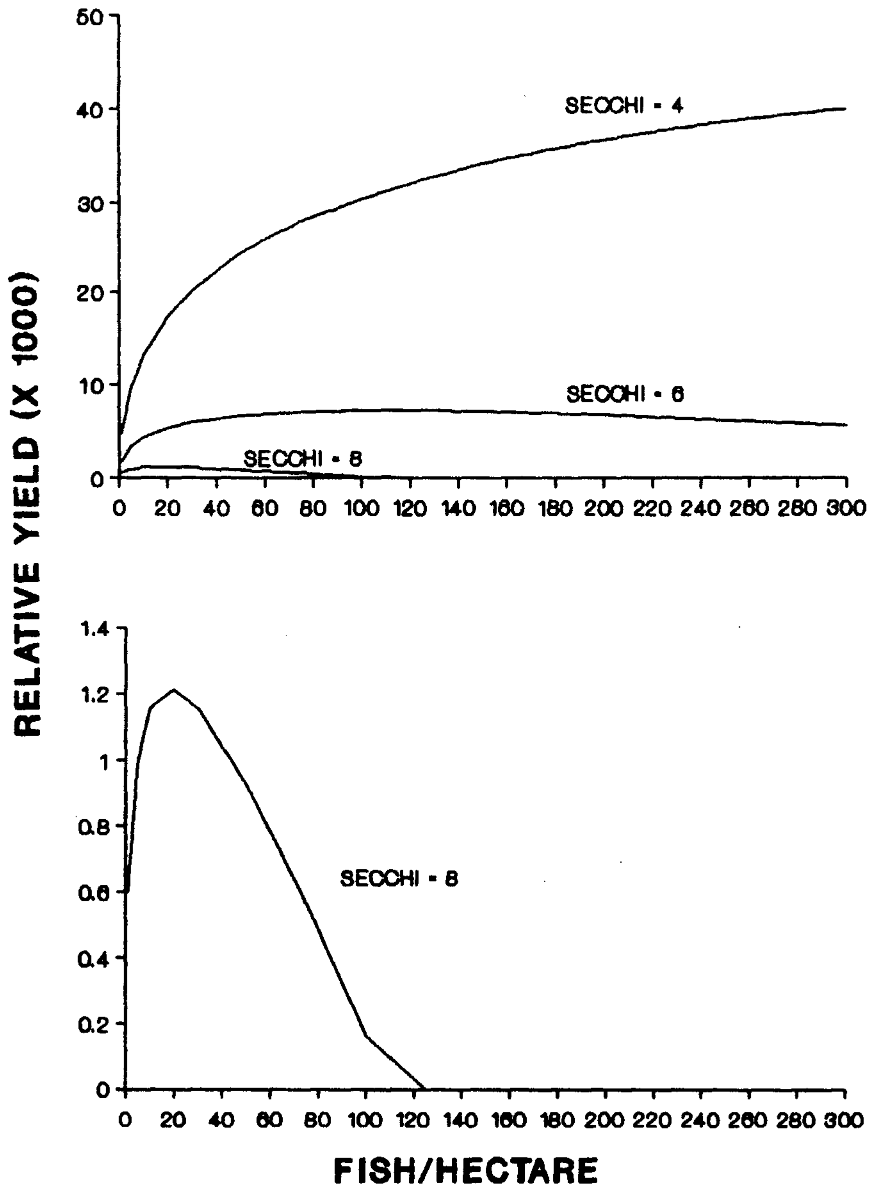

Figure 3. Predictions of relative vulnerability to anglers for age 3+ kokanee at varied densities and in waters at three levels of productivity. Productivity is represented by Secchi transparency.

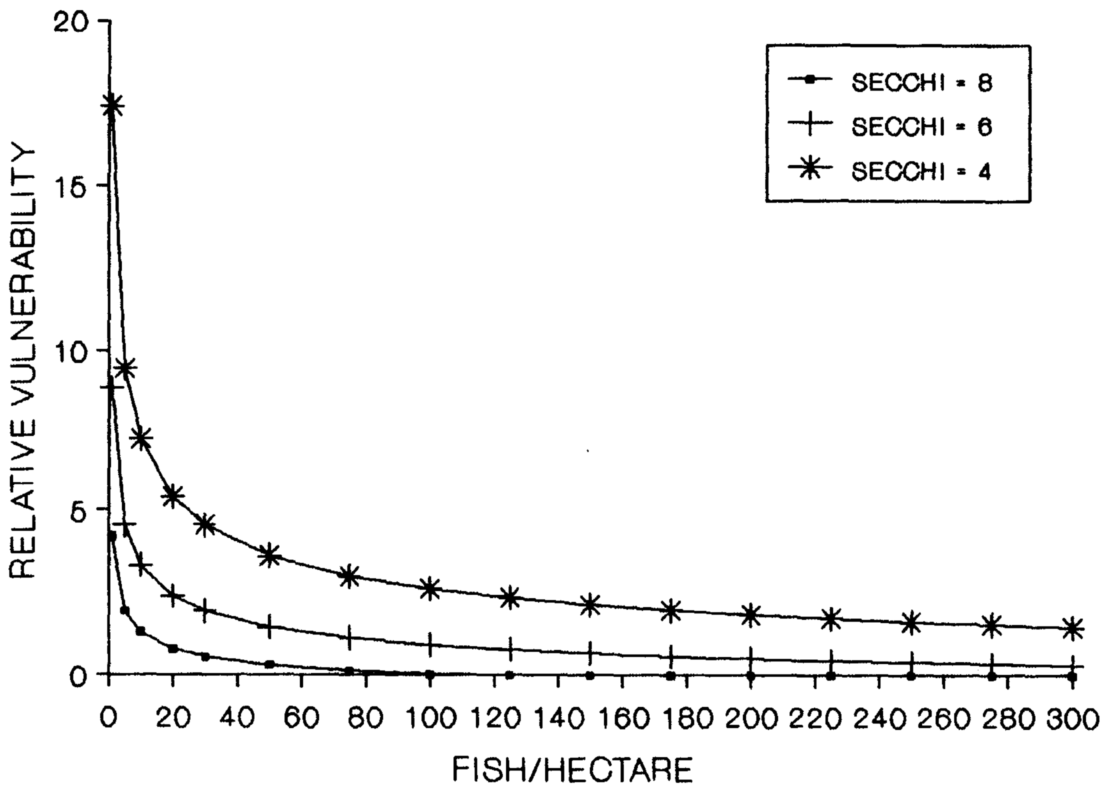

Figure 4. Predictions of relative yield (no units) of age 3+ kokanee at varied densities and in waters at three levels of productivity. Productivity is represented by Secchi transparency.

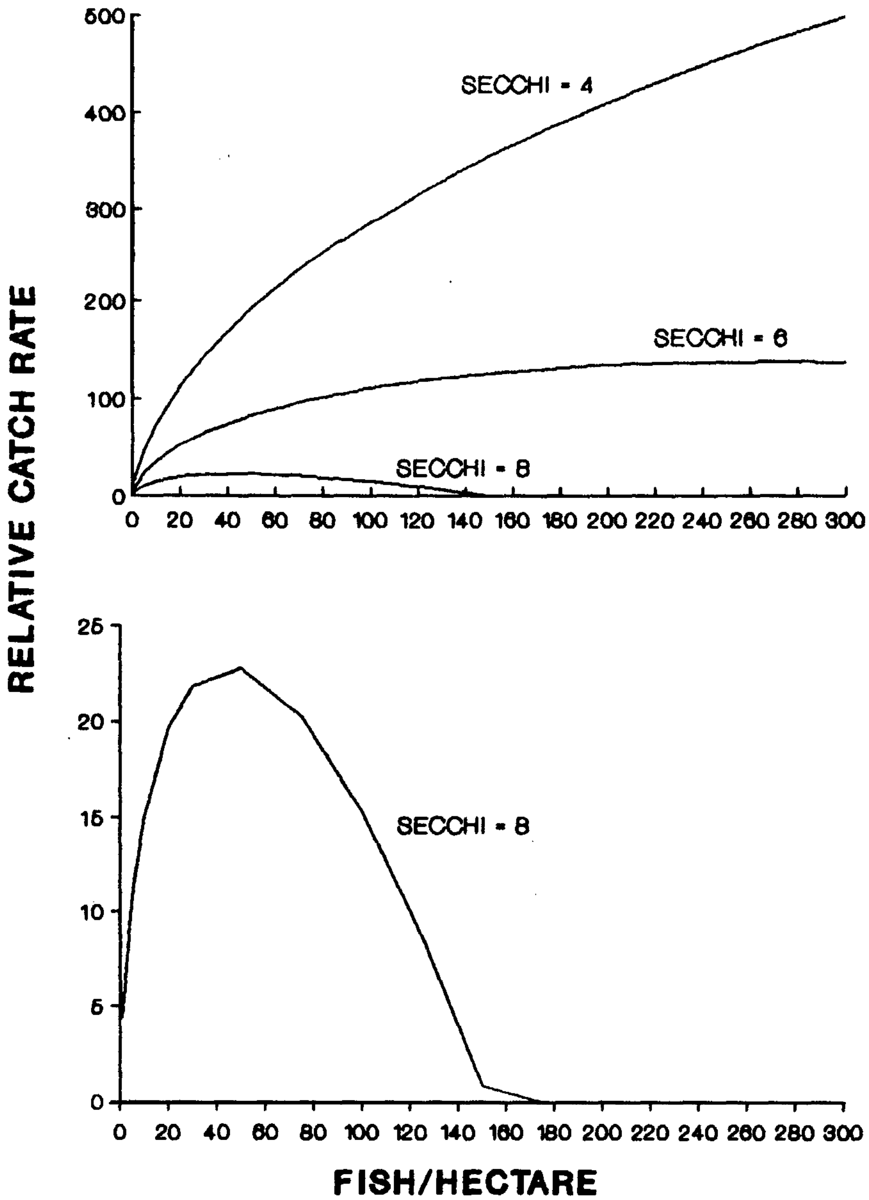

Figure 5. Predictions of relative catch rate (no units) of age 3+ kokanee at varied densities and in waters at three levels of productivity. Productivitiy is represented by Secchi transparency.

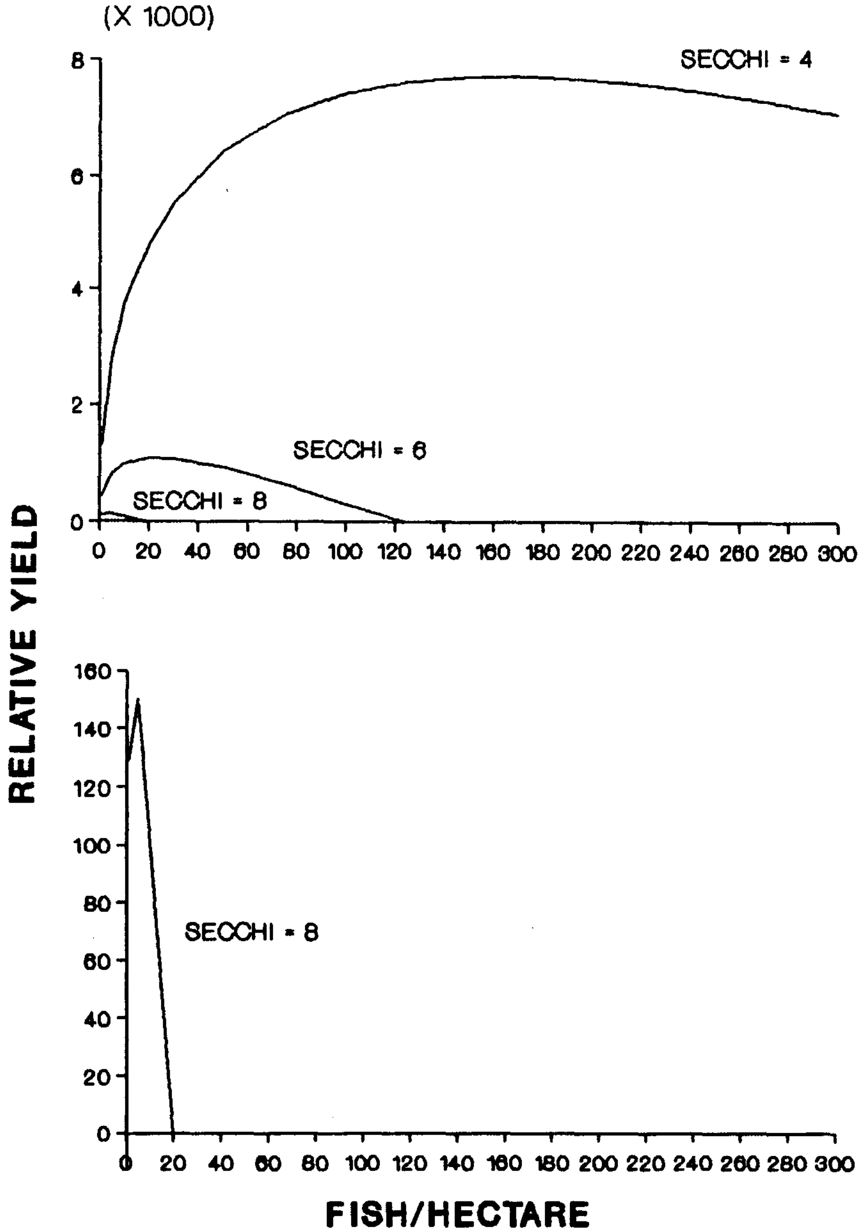

Figure 6. Predictions of relative yield (no units) of age 2+ kokanee at varied densities and in waters at three levels of productivity. Productivity is represented by Secchi transparency.

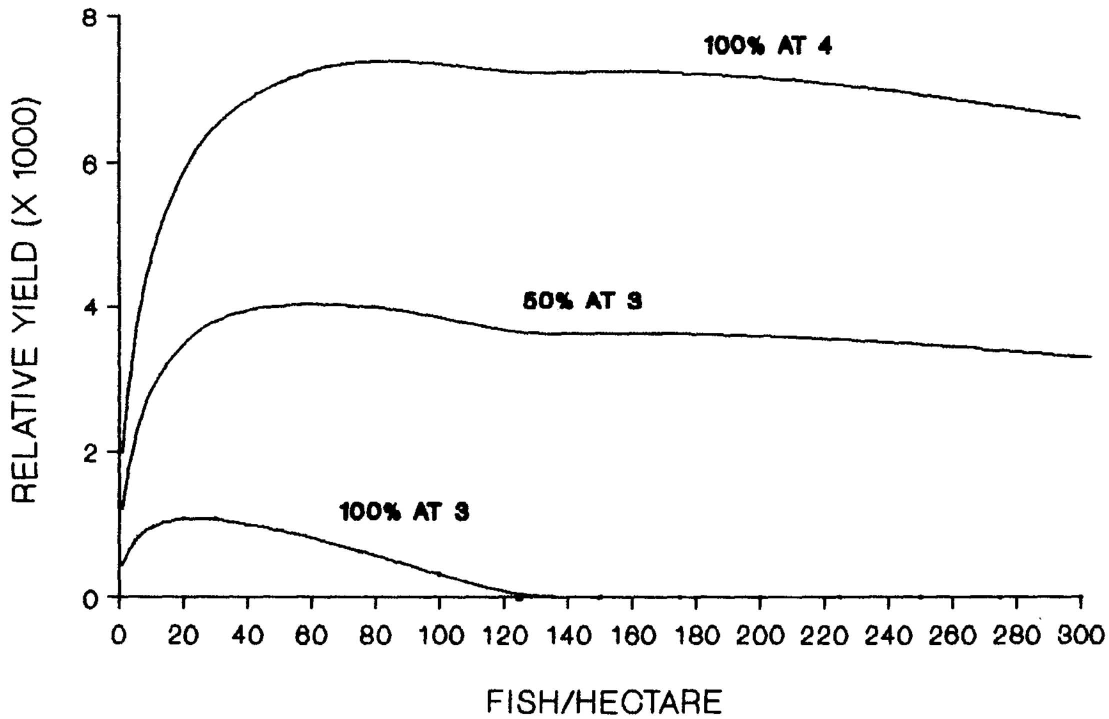

Figure 7. Predictions of relative yield (no units) for age 2+ and age 3+ kokanee combined with varied age at maturity and density. Productivity was held constant at Secchi = 6.

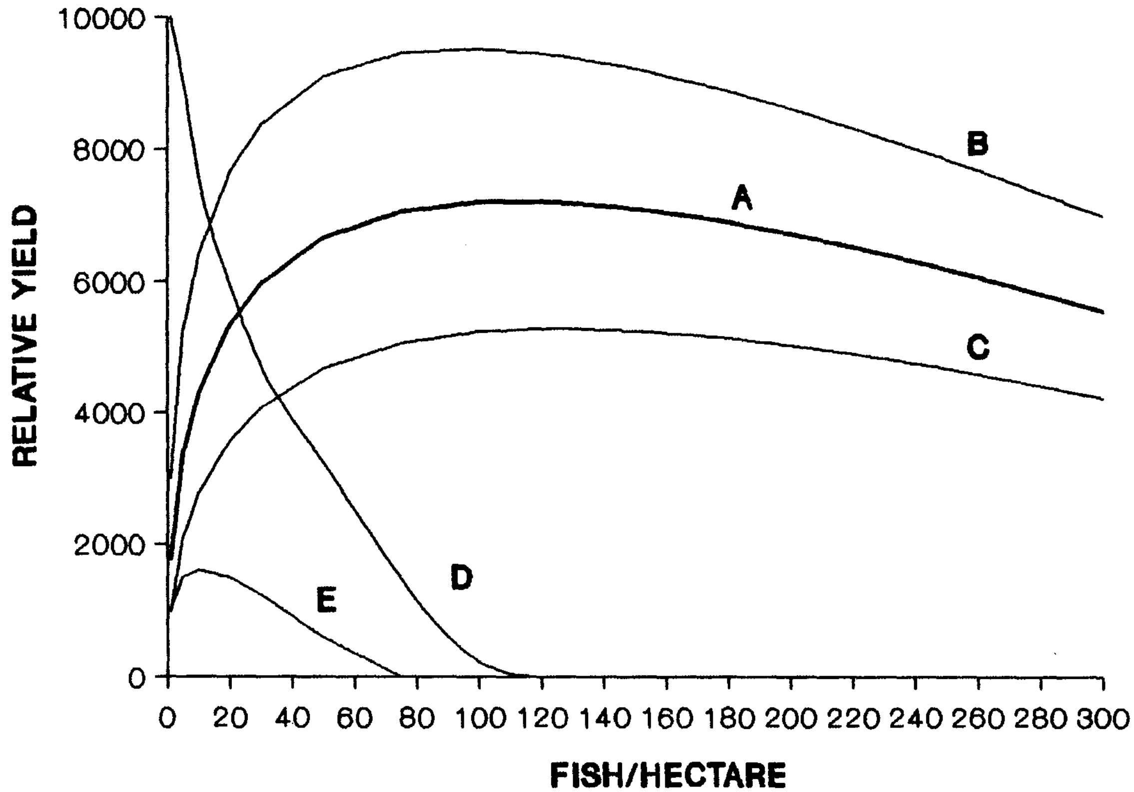

Figure 8. Uncertainty in predictions of relative yield (no units) for age 3+ kokanee. Each response is the result of a change in parameters for the vulnerability model. A represents the base simulation; B an increase in slope; C a decrease in slope; D an increase in the x intercept and an increase in slope; and E an increase in the x intercept. Parameter values are summarized in Table 4 and Figure 2B.

Empirical Responses

Complete creel and population data were available for twelve observations (Table 5). Catch rate was significantly ($p < 0.05$) correlated with both fish density and Secchi depth (Table 6). Effort was significantly correlated with fish density and catch rate. The data suggest asymptotic responses in catch rate and effort and a domed response in yield (Figure 9). Effort appeared to be directly related to catch rate (Figure 10). Regressions incorporating second independent variables (fish density, Secchi depth, or fish length) did not explain significantly more of the variation in catch rate, yield, or effort than any single variable.

Stocking Rates

Survival of hatchery-produced fry from release to the first fall was estimated in Pend Oreille Lake to range from about 6% to 30% (Bowles et al. 1989). The Pend Oreille program goal is for survival of 30%. Consistent survival between 20% and 30% should be possible with proper release size and timing (Bowles et al. 1989). Survival estimated between older age classes in all of our study lakes ranged from 57% to 90% (Table 7). With good fry releases, we estimate survival from release to age 3+ should range from 6% to 12%. Survival from hatchery fry to fish fully recruited in the fishery has been near 10% in other lakes (Parkinson 1986). Initial stocking rates for most lakes should therefore range from about 8 to 17 times the target density at age 3+.

DISCUSSION

Relative vulnerability was strongly related to fish size. Size selectivity by fishing gears is common (Beamesderfer and Rieman 1988; Ricker 1975; Ralston 1990). Size- or age-regulated recruitment to a fishery is also well established (Ricker 1975). The mechanism controlling vulnerability to angling has not been defined for kokanee. Size-related differences in fish distribution, feeding habits, swimming speed, and the relative size of gear or bait to the fishes mouth might all be important. Estimated vulnerability was not constant among years or between populations. Vulnerability may vary with environmental conditions, or perhaps the population of anglers. Kokanee anglers in Idaho use a variety of lures or baits, with a particular gear often a matter of local preference. Anglers we censused on Coeur d'Alene Lake and Spirit Lake often still fished with small baited jigs ("handlining"), while anglers on other waters fished exclusively by trolling.

Although the slope may vary, vulnerability should be expected to increase with size, perhaps dramatically. Our data for Spirit Lake, for example, show that 270 mm kokanee could be caught at 20 times the rate of fish 230 mm long. Such differences should have an important influence on exploitation among size and age classes and on the fishery itself.

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Table 5. Available observations of kokanee density (age 3+), length (age 3+), catch rate, yield to angler, and total effort for anglers seeking kokanee.

Water year	Age 3+ density (no/ha)	Sept. length (mm)	Catch rate (no/hr)	Yield (kg/hr)	Angler effort (hours)	Source
Pend Oreille Lake						
1977	29	235	1.60	0.17	136,000	
1978	57	235	1.38	0.16	118,210	Rieman 1981
1979	30	245	1.34	0.17	137,000	Ellis & Bowler 1980
1980	46	255	1.40	0.19	121,000	Ellis & Bowler 1981
1985	16	262	1.03	0.14	64,700	Bowles et al. 1987
Priest Lake						
1978	7	245	0.29	0.03	15,000	Bowler 1979 Bowler 1981
Payette Lake						
1988	9	240	0.08	0.02	28,000	Scully and Anderson (1989) Agency files
Coeur d'Alene Lake						
1979	47	245	1.22	0.07	172,000	Rieman & Labolle 1980
1980	110	225	1.12	0.08	228,000	Rieman & Ward 1981
Spirit Lake						
1981	161	260	1.26	0.11	71,000	Ellis et al. 1982
Dworshak Reservoir						
1988	10	310	1.47	0.21	140,416	Mauser 1989
1989			1.31	0.16	130,343	Agency files
Odell Lake						
1974	10	310	0.55	0.13	114,000	Lewis 1975

TABT1.JB2

Table 6. Pearson Correlation coefficients for data used to describe relationships in kokanee fisheries with fish density, fish length, and water productivity (Secchi depth). Significant correlations (p s 0.05) are noted by *.

	Angler effort	Catch rate	Relative yield
Density	0.298	0.346	-0.059
Log (Density)	0.523*	0.587*	0.135
Catch Rate	0.626*	-	-
Log (Catch Rate)	0.647*	-	-
Secchi	-0.593*	-0.706*	-0.392
Log (Secchi)	-0.523*	-0.638*	-0.319

TABT1.JB2

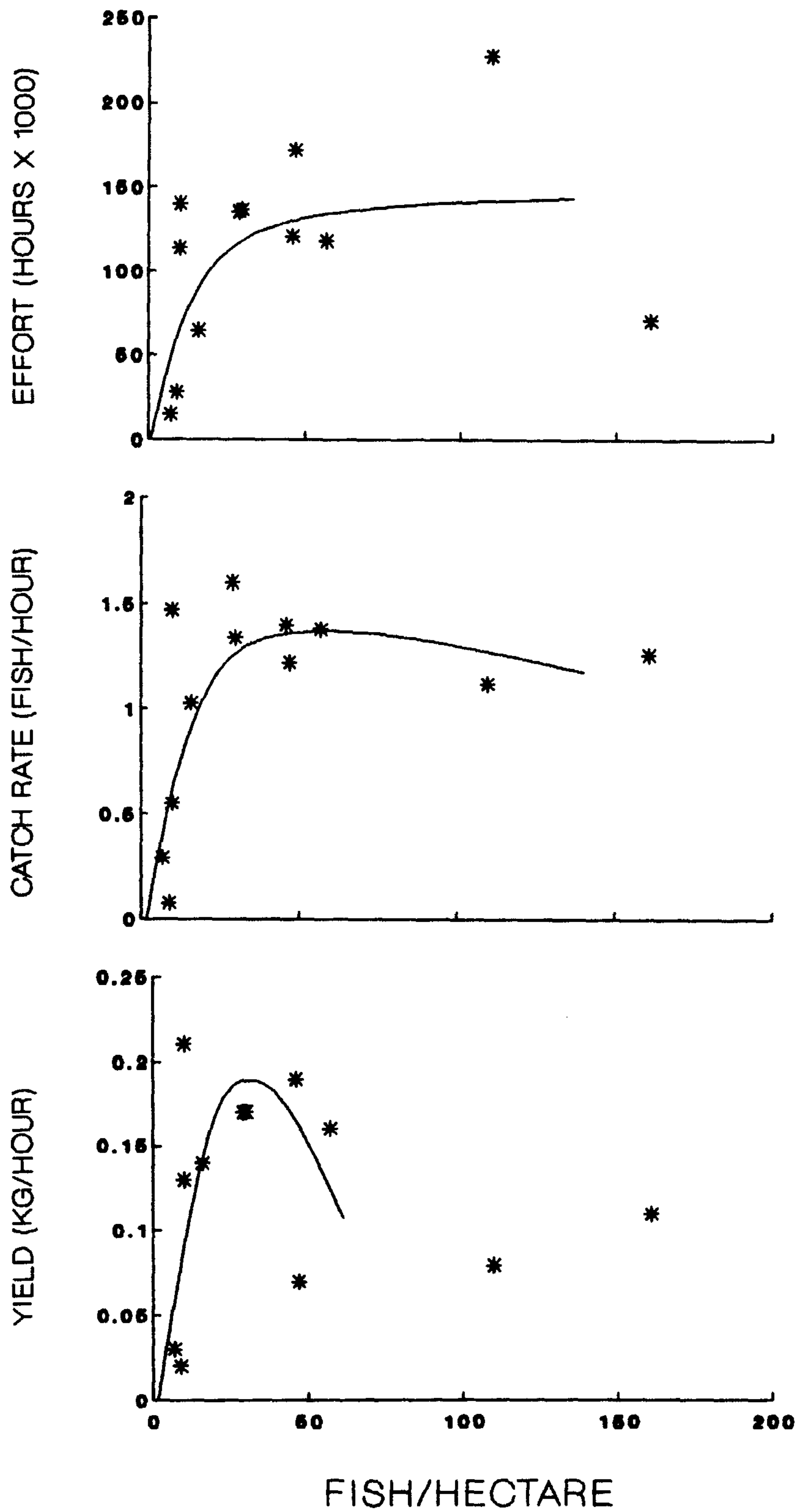

Figure 9. Relationships of estimated angler effort, catch rate, and yield to the angler, against fish density in actual kokanee fisheries. Lines were fit by inspection. Data are summarized in Table 5.

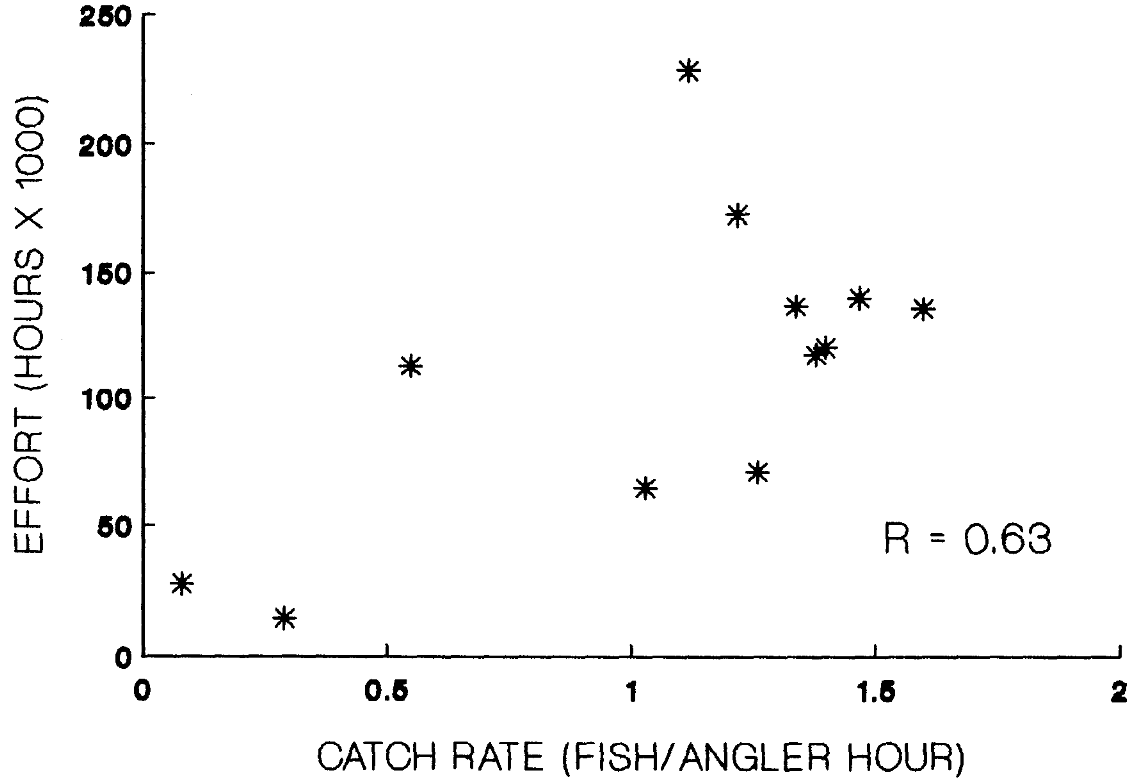

Figure 10. Relationship of estimated angler effort against catch rate in actual kokanee fisheries. Data are summarized in Table 5.

Table 7. Summary of kokanee survival from hatchery release to age 3+. Estimates for hatchery to 0+ are from Bowles et al. (1989). The remaining estimates are from trawl sampling of kokanee densities in sequential years as described in Job 1 of this report.

Age	Survival	
Hatchery Release to 0+	0.06 – 0.30	---
0+ to 1+	0.60 – 0.30	18
1+ to 2+	0.90	28
2+ to 3+	0.57	27

TABT1.JB2

Obviously, exploitation could be higher in older age classes. Given similar effort, the level of exploitation should also be higher in populations with faster growing individuals. We predicted that relative vulnerability should increase in exponential form with decreasing density. If fishing effort remained stable, a decline in fish density should result in increased exploitation. Several authors have shown that exploitation of age-2+ kokanee was substantially less than that of age-3+ and older fish (Lewis 1974; Rieman and Ward 1981; Bowles et al. 1986; Klein 1979). Lewis' (1974) data also indicate that exploitation can be higher in years of lower fish densities.

Our results suggest fishing mortality could be depensatory (increasing with decreasing number) and, therefore, could be a destabilizing force. Populations operating at low densities may produce very large fish that support popular fisheries. If fishing effort is relatively high and the population is unstable, collapse is possible. Flathead Lake, Montana, once supported a popular fishery for large (270 to 400 mm) kokanee. Kokanee in the catch increased in size to the largest recorded shortly before the fishery collapsed in 1986 (Hanzel 1984, 1987; Hanzel et al. 1988). Management goals were for large fish (Graham et al. 1980), even though the fishery was exploited at a relatively high rate. Data from Frailey et al. (1986) indicate that in Flathead Lake the adult fish were exploited at 70% to 75% several years before the collapse. If the population declined, as suggested by increasing size of fish, and effort remained stable, increasing vulnerability may have pushed exploitation even higher.

The risk of collapse may be more important in productive lakes where fast growth results in high vulnerability. The effects of exploitation might also be more serious in lakes with other depensatory mortalities, such as predation. Any lake operating at low densities (less than 10 to 20 fish/hectare) may risk over-exploitation if fishing effort is high.

High kokanee densities also should be a concern in fishery management. Our models predicted that relative yield and catch rate will not increase proportionally with density and may, in fact, decline. We should anticipate little benefit to densities of kokanee (age 3+) in excess of 40 to 50 fish/hectare for lakes of intermediate productivity (summer mean Secchi about 6 m). More productive lakes could support larger numbers, but in low productivity lakes, densities higher than 20 kokanee/hectare should result in much poorer fishing than lower numbers. In fisheries supported by hatchery production, the ratio of fishery benefits to cost of management should decline dramatically as populations approach these densities.

Productivity of the rearing environment will have an important influence on the quality of a kokanee fishery. Our results indicate that differences in productivity represented by Secchi depths of 6 to 8 m can produce a 4-fold difference in relative yield. Differences of 4 to 8 m can result in a 13-fold range of relative yield. We should not anticipate similar fisheries in all lakes. We may also expect a substantial decline in fisheries in aging reservoirs. Unproductive lakes may pose a particularly difficult management problem. The range of suitable fish densities could be quite narrow. Densities

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much in excess of 20 fish/hectare may result in poor fisheries, while those substantially lower may risk collapse.

Age-at-maturity should also influence the quality of a fishery. We predicted, for example, that a shift of mean age-at-maturity from 3.5 to 4.0 would produce the same increase in yield as an increase in density from 10 to 60 fish/hectare (Secchi of 6 m). A shift to earlier spawning could result in a substantial loss in the fishery simply because fish die before they become readily available to the anglers. In Coeur d'Alene Lake, a decline in the kokanee fishery was associated with a shift to younger, but more numerous, adults. Conversely, improved kokanee fishing in Pend Oreille Lake has been associated with larger and older adults without any appreciable change in kokanee density (Melo Maiolie, Idaho Fish and Game Region 1, personal communication; Bowles et al. 1988). We suggest that varying age-at-maturity explains much of the variation in these fisheries.

Age-at-maturity may be influenced through the environment and genotype. Faster growing fish often mature earlier (Graynoth 1986; Kato 1980; Lewis 1971; Klein 1979), but stock or genetic influences may also be important with kokanee (Lewis 1971) and sockeye (Rogers 1987; Ricker 1982). Lewis (1971) found that four stocks of kokanee showed consistent differences in age-at-maturity.

The size-at-maturity and, thus, size of fish available to anglers may depend on growth of sub-adult fish. Kato (1980) found in a population with fast growth that variation in age-at-maturity explained almost all of the variation in adult size. Lewis (1971) found a similar result in relatively productive lakes, but in unproductive lakes he found no relationship between adult size and age-at-maturity. When growth was slow, an additional year of life did not produce a difference in size greater than that between the mature and immature fish in the cohort (Figure 11). The benefits of delayed maturity will probably depend on growth rate of individuals. In unproductive lakes or populations operating at very high densities, **a** delay may produce little benefit to the fishery.

Still, the ability to delay maturity could provide substantial benefits in some fisheries. Eric Parkinson (British Columbia Fish and Wildlife, unpublished manuscript) has proposed that size of fish could be maximized by balancing the tradeoffs between growth and age-at-maturity. Assuming that faster growing fish mature earlier, intermediate rather than low densities will produce the largest fish. Growth and, thus, size-at-maturity might be controlled by regulating density of the population through stocking. In some fishes, age-at-maturity appears to be related to initial growth or size of juveniles (Randall et al. 1986; Bradford and Peterman 1987; Meerburg 1986). As an alternative, it may be possible to influence age-at-maturity by controlling initial growth of fish produced in hatcheries. It may also be possible to influence age-at-maturity through selection of the donor stock (Lewis 1971), selective breeding of a stock, or through genetic sterilization. The manipulation of age-at-maturity is not clearly possible, but the benefits could be large. Further work on age-at-maturity should be useful.

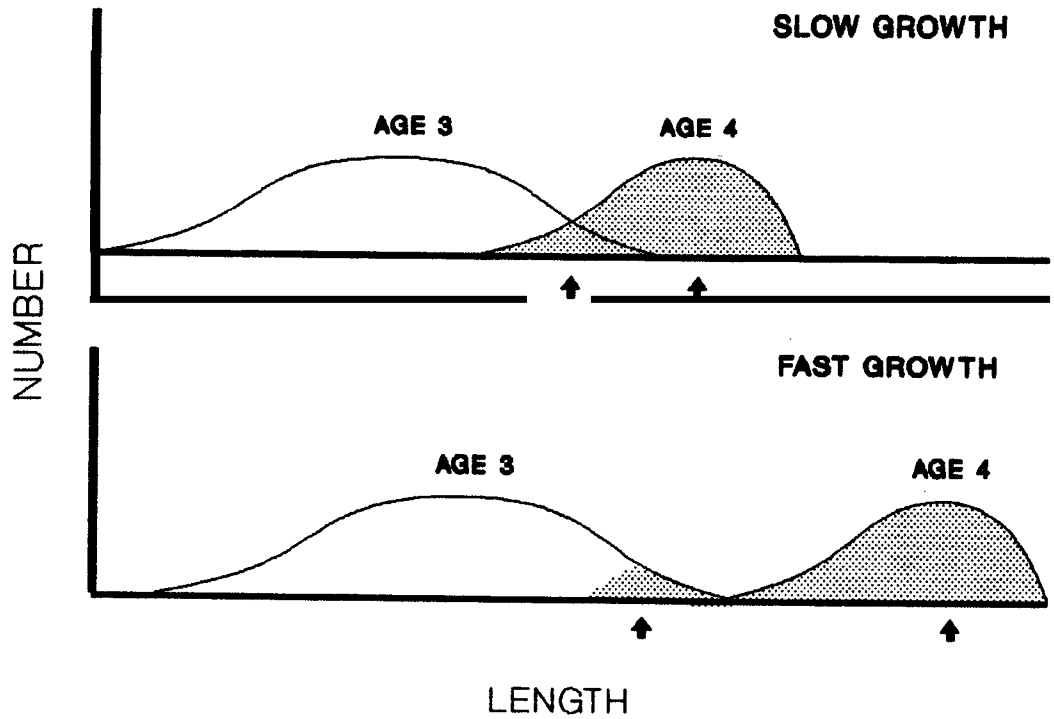

Figure 11. Relative differences in size at maturity for kokanee maturing at age 3 and age 4 under two different rates of growth. Shaded areas represent mature fish. The arrows represent the mean size at maturity expected when the rate of maturity at age is the same in both populations. The figure was conceptualized from the results of Lewis (1971) and Kato (1980).

Given our range of survival from hatchery fry to age 3, optimum stocking rates could range from 8 to 17 times the target densities. Stocking rates should be less if there is consistent natural production. Because our models and survival are uncertain, the stocking recommendations have a wide range. Because of the uncertainty, stocking should proceed in experimental fashion. We suggest initial stocking rates of about 10 times the target density for age-3 fish. Stocking densities should be held constant for several years until a pattern of survival and growth can be established. Once a base of information is established, stocking rates can be altered to move the fishery toward the management goal. Our models should be particularly useful at that point to predict the relative change in fish density and stocking necessary produce the desired changes.

Target densities can be based on desired size of fish or relative changes in catch rate or yield. An index of productivity will be necessary for a manager to determine realistic goals. Densities exceeding those described above are not advised unless the primary use of kokanee will be as forage for predators. Benefit to cost for most hatchery-supported programs will probably be realized at the lowest densities that still generate significant angler interest.

Limitations of the Analysis

Our predictions of the density-related tradeoffs in kokanee fisheries was based on a simplistic approach linking empirical models of vulnerability and of growth. We did not consider the effects of exploitation on fish abundance. Our results are also relative. We do not predict actual yield, which would vary with fishing effort in addition to fish size and density. Our results best predict the quality of fishing where recruitment is not influenced by exploitation of the adult stock.

The number of observations of growth and vulnerability were limited at low densities and fish larger than 270 mm. Results predicted for populations operating below about 10 fish/hectare thus represent extrapolations beyond the range of our data. Compensatory responses in those ranges may be much different from what we anticipate through our models.

Our observations were limited to kokanee of age 3+ and younger. Many populations have significant numbers of fish in older age classes. We believe differences resulting from fish maturing later than age 3+ should be similar to those predicted between age 2+ and age 3+. Those differences could be less, however, because growth rate continues to decline with size, creating a declining differential in size between age classes. An asymptote in growth means that the fishery benefits from delaying maturity by a year will decline with increasing age. The effect should be similar to that predicted from slower growth in unproductive lakes.

Our simulations assumed that catch rates are directly proportional to density of constant size fish. In reality, catch rates probably will not increase in direct proportion to density. Rather, catch rates should increase at a declining rate (see Rieman and Apperson 1989). If that is the case, our predictions of catch rate and yield are optimistic. Catch rate and yield may increase with densities at a rate that declines faster than predicted. Optimum densities could be even lower than those predicted here.

Our analysis of uncertainty showed that the shape of the vulnerability response also will have an important influence on the fishery at varying densities. The slope of the response influenced the magnitude of catch rate and yield but did not alter the basic shape and, thus, would not influence prediction of optimum densities. The intercept of the response, however, did have an important effect. Increasing the intercept produced a more dramatic decline in yield at higher densities. Again, optimum densities could be lower than suggested by our predictions.

Finally, our models incorporate sampling error and inherent variation in growth and vulnerability that we could not explain. Our predictions are not precise and do not include random errors. We also could not incorporate the effects of other variables that must influence growth (see Job 1 of this report). Continued monitoring **of** kokanee fisheries should lead to more precise models and a better understanding of other important variables. An empirical approach predicting yield and catch rate directly from observations over a larger number of lakes could eliminate much of the uncertainty in our models. The empirical responses summarized in this report were similar to our predicted responses, but those data are too limited to provide accurate predictions themselves. Better empirical models should also be possible with a routine monitoring program.

Summary and Conclusions

Our results support several important conclusions. Size and vulnerability will increase with declining densities of kokanee. Exploitation may increase dramatically and poses a risk of collapse in naturally-supported populations. Length-at-age for kokanee can be used as a rough index of density and the risk of overharvest or other depensatory mortality. Age-4 spawners (aged as 3+ in final summer) larger than 300 mm, 250 mm, or 230 mm should be common at densities of 10 to 20 fish/hectare in productive (Secchi = 4), intermediate, and unproductive (Secchi = 8) waters, respectively. Larger fish in waters supporting heavy fishing pressure or important predators should be a danger signal to the manager.

The quality of a fishery will not increase directly with fish density and, in unproductive lakes, may decline. Optimum densities will depend on lake productivity, but probably are lower than previously anticipated. Current goals for rehabilitation of the Pend Oreille kokanee fishery are about 800 fry, or 80 adults per hectare. Unless age-at-maturity shifts consistently to age 5, or unless mortality to predators increases, we expect little benefit from pushing hatchery production to those goals. Stocking rates of 100 to 500 fry per hectare should be adequate for all but the most productive lakes. Even in productive waters, stocking rates on the lower end may provide the greatest benefit.

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Productivity will have a dramatic influence on the quality of a fishery. Realistic management goals will reflect the potential of a system. Kokanee waters can be characterized with data on Secchi transparency, chlorophyll, and total phosphorous for comparison with data presented here.

Age-at-maturity may have a dramatic influence on quality of a fishery. Management of spawning age could be very useful and further research should focus in this area.

Our results should not be used to establish hard goals but, rather, to establish some initial targets for fish density and stocking rates that will be modified through adaptive management. Our results should be most useful in helping managers understand the relative potential of different fisheries and the relative changes in growth, catch rate, or yield that can be expected with changes in management. Continued monitoring can improve our ability to predict and manage these fisheries.

RECOMMENDATIONS

1) Populations operating at low densities (10 to 20 fish/hectare) may risk collapse through overexploitation or other depensatory mortality. Managers should use information on the relative productivity of a water and kokanee length-at-age as an index of density. Unusually large fish should be viewed as a danger signal, harvest should be managed carefully, and stocking of predators should be curtailed.

2) In lakes without natural reproduction, initial kokanee stocking rates should be 100 to 500 fry per hectare. The higher rates should be used in more productive lakes. Stocking should be held constant for at least four years, or until a pattern of growth and survival is established, and then altered in an experimental fashion to approach the management goal.

3) Management goals, such as size of fish, should be based on the relative productivity of the water body. We lack consistent data on many lakes and reservoirs that are, or will be, managed for kokanee. At a minimum, sampling to describe summer mean Secchi transparency should be done wherever possible. Other data on total phosphorus, lake morphometry, conductance, and summer mean chlorophyll should be considered as part of a statewide inventory.

4) Age-at-maturity will have **a** major influence on yield in many lakes. An ability to manage age-at-maturity could be more useful than other tools. New research on mechanisms controlling age-at-maturity in kokanee should be pursued. In lakes where spawning populations are routinely sampled, age frequency should be estimated from otoliths.

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Virgil Moore, Ed Bowles, and Tim Cochnauer helped with the design of this work. Melo Maiolie was particularly helpful, providing critical and thoughtful discussion and encouraging us to explore the empirical models. Larry La Bolle, Vern Ellis, and Barbara Ward collected much of the creel data.

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JOB PERFORMANCE REPORT

State of: **Idaho**

Project No: **F-72-R-12**

Subproject No.: **II**

Study No.: **I**

Job No.: **III**

Name: **Status and Analysis of Salmonid Fisheries**

Title: **Kokanee Population Dynamics**

Job 3: **Regional Data Base**

Period Covered: **March 1, 1989 to February 28, 1990**

ABSTRACT

We created a computer data base of biological and fishery information from 74 kokanee lakes and reservoirs throughout the western states and British Columbia. Kokanee yield estimates were available for 28 of these lakes and reservoirs. Complete yield and productivity information were limited to lakes of low or intermediate productivity. We found a positive relationship (r^2 = .72) between effort (rod hours/hectare) and kokanee yield. The data suggest several relationships between yield and productivity. Morphoedaphic index and chlorophyll 'a' showed stronger relationships with yield in lakes at elevations <1,000 m. Total phosphorus and Secchi transparency showed stronger relationships with yield in lakes at elevations >1,000 m. Development of empirical models of kokanee yield will require more complete estimates of yield and observations over a wider range of lake productivity. Larger sample size will also allow the incorporation of more than one independent variable into our models.

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INTRODUCTION

There is probably a wide range in the potential yield of kokanee fisheries found throughout Idaho and the Pacific Northwest region (Job 2 this report). The biological and physical characteristics of the lake, the kokanee population, and the anglers all can affect the yield in a fishery. Managers could use a summary of information from a variety of kokanee lakes to provide perspective. If the information is standardized and readily available, evaluations and comparisons could be made to develop more realistic goals for individual kokanee fisheries.

Our objectives were: 1) to compile such a data base; and 2) to develop empirical models that would allow the prediction of potential kokanee yield based on the characteristics of the lake or reservoir of interest.

Many estimators of fish yield have been proposed. Methods range from simple empirically-derived indices of fish production to elaborate ecosystem simulation models (Leach et al. 1987). Empirically-derived estimators of fish yield include measures of lake morphology, water chemistry, biological indices, and derived ratios such as morphoedaphic index (total dissolved solids/mean depth).

We hypothesized that potential yield (per surface area) for kokanee is a function primarily of lake productivity and, secondarily, of other physical and biological characteristics of the system. Realized yield should be a function of the potential yield and fishing effort (Goddard et al. 1987). A model of potential yield should be possible given enough observations. Realized yield should be possible by incorporating effort as a variable. To be useful for the manager, the data required for the model must be easily obtained from normal physical and biological inventory. Therefore, we limited our analyses to those kinds of data.

We began by conducting a region-wide survey of existing biological and fishery information. We gathered management reports and agency files to summarize data for Idaho lakes and contacted fishery managers and researchers to fill holes in the data when information was available. We then standardized the information and summarized it on a computer data base.

METHODS

We compiled information on lake characteristics, the kokanee population, and the fishery from kokanee lakes and reservoirs throughout several western states and British Columbia (Appendix A). Lake characteristics include lake morphometry (surface area, volume, and depth), and measures of productivity (morphoedaphic index (MEI), mean summer Secchi depth, total phosphorus, and chlorophyll 'a'). We expressed MEI as conductivity/mean depth rather than total dissolved solids/mean depth as defined by Ryder (1965) because conductivity was the measurement normally available. Conductivity correlates significantly with

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total dissolved solids and may be used in place of total dissolved solids (Hutchinson 1957, Ryder et al. 1974). Kokanee population data includes estimates of kokanee abundance and growth, spawning escapement, and age-at-maturity. Harvest data include yearly estimates of kokanee yield, predator yield, and angler effort. We also compiled a species composition list for each lake. The format of all variables and a summary of observations by variable is outlined in Appendix B.

All data came from existing files and reports or personal communication. We requested information directly from Montana Department of Fish, Wildlife and Parks, Washington Department of Wildlife, and the Ministry of Environment in British Columbia. Data for Oregon, Utah, and Colorado lakes were taken from published literature and through personal communication. We gathered data for Idaho lakes from existing regional management reports and agency files.

In an attempt to be consistent in our data, we designated several conventions. We designated age change at the time of annulus formation in the spring. Therefore, a fish that was collected in the first summer/fall was age 0+. Likewise, a spawner maturing after the third summer/fall was age 2+. When designating age-at-maturity, if spawners were split evenly between two ages (i.e. 50% spawn at age 3 and 50% spawn at age 4) we listed the predominate age as 3.5. We requested time of sample (month) be noted so length data could be standardized by growth projections. Lengths that we entered into the data base, however, are the actual measured lengths (mm total length) at the time of collection.

We requested ranges, as well as mean values, for estimates of spawning escapement, hatchery supplementation, kokanee abundance, harvest, and angler effort. Where possible, mean estimates reflect the mean of the highest five consecutive years of available data. The sample size was noted if less than five consecutive years of data were available.

Whenever possible, we calculated kokanee yield estimates (kg/hectare/ year) from harvest data (number and mean size). When mean size of fish in the harvest was given as length rather than weight, we calculated weight using the length/weight relationship for kokanee in Pend Oreille Lake.

We used dBase III Plus to set up three data files to store and manage the information. One data file, Regional.dbf, contains the majority of the information. Two supporting data files are Species.dbf (species composition), and Dsource.dbf (sources of information).

Regional.dbf contains 64 character or memo fields (Appendix B). The lakes are sorted by state or province using the index file State.ndx. We set up three dBase report forms: Lake.frm (Appendix C), Popn.frm (Appendix D), and Fishery.frm (Appendix E). The report forms can be used to generate hard copies of selected information from Regional.dbf.

Species.dbf contains 84 data fields (one for each species). An 'x' is placed in each species field where that species occurs for each observation. Abbreviations for the species names are in Appendix F, as well as a copy of the data reports Sp_Comp.frm and Sp_Comp2.frm.

Dsource.dbf contains a numbered list of the sources of information for the data (Appendix G). The sources are cross-referenced in Regional.dbf by number.

We summarized the total number of observations that were available in each data field. We plotted frequency distributions of the lakes summarized by total phosphorus, mean summer Secchi depth, chlorophyll 'a', and kokanee yield for all lakes in the data base where the specific data were available.

To test our hypothesis that yield is a function of productivity and effort, we plotted yield against each of four productivity indices. We used correlation and regression analysis to examine relationships between yield (kg/hectare) and effort (hour/hectare) and between yield and each of four indices of productivity. We then stratified the data by elevation to compensate for possible differences in growing season. The distribution in elevation of the lakes with yield estimates had a break in the data at 1,000 m above mean sea level (Figure 1). Correlations of yield with MEI, total phosphorus, chlorophyll 'a', and secchi were compared for lakes at altitudes of s1,000 m, and >1,000 m with those from the whole data set.

RESULTS

The data base includes a total of 74 lakes and reservoirs and 64 data fields (Appendix B). Very few observations are complete for all 64 variables.

The 74 lakes that we sumarized varied in surface area from 14.2 to 38,348 hectares (Appendix C). Mean depth ranged from 5.2 to 164 m. Forty-eight of the lakes are in the state of Washington, 16 are in Idaho, 4 in Colorado, 2 each in Utah and British Columbia, and 1 each in Oregon and Montana. Elevations ranged from 4 to 2,524 m msl.

Most of the lakes in the data base are relatively unproductive (Figure 2). Total phosphorus ranged from 3 to 94 ug/l (n = 56). Total phosphorus levels in 50% of the lakes were below 20 ug/l. Twenty-nine percent of the lakes had total phosphorus levels <10 ug/l. Secchi depths ranged from 1.0 to 14.0 m (n = 68), with 50% between 4 and 8 m. Chlorophyll 'a' values ranged from 0.7 to 15.0 ug/l (n = 30), with 50% less than 2.5 ug/l.

Kokanee yield estimates were available for 28 lakes and reservoirs (Table 1). Yield estimates ranged from 0.023 kg/hectare in Alturas Lake, Idaho (Secchi depth = 13.0 m) to 12.741 kg/hectare in Spirit Lake, Idaho (secchi depth = 3.9 m). Fifty percent of the estimates are between 0.017 and 2 kg/hectare (Figure 1). Yield estimates were not available for any of the lakes with concentrations of total phosphorus and chlorophyll 'a' above 50 ug/l and 6 ug/l, respectively. Six of the 28 yield estimates represent either exceptionally low years or partial estimates (ie. declines following the Mt. St. Helens eruption, partial seasons, or partial lake estimates) (Table 1).

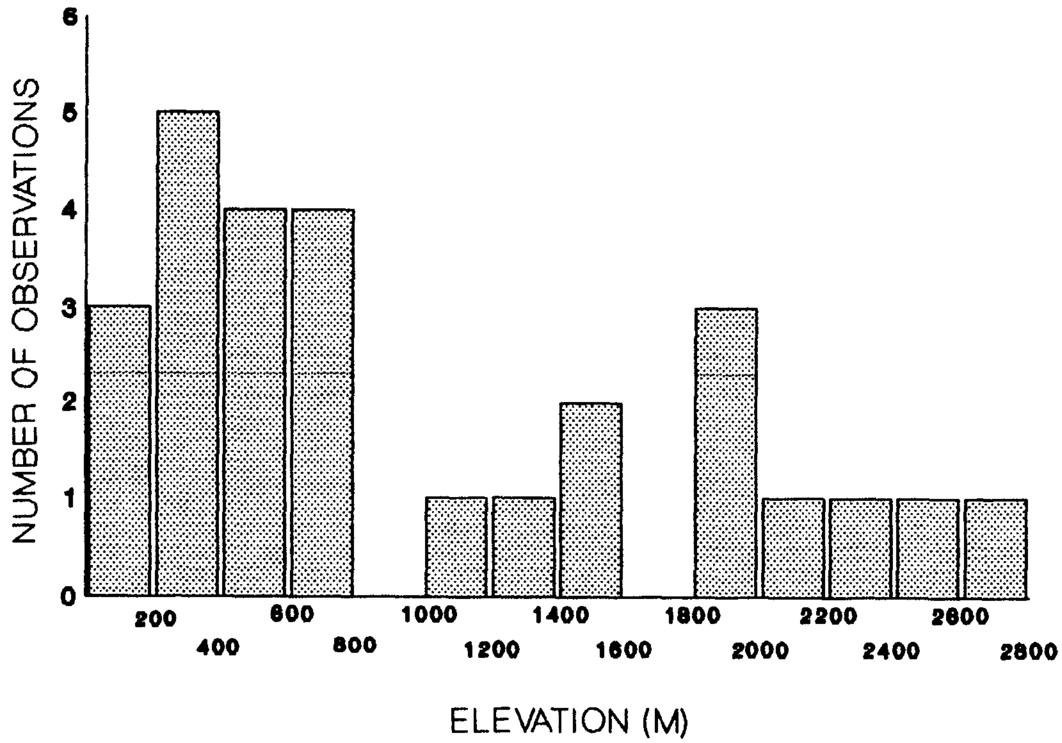

Figure 1. Frequency distribution of observations by elevation (m above mean sea level) for 28 lakes where yield estimates were available.

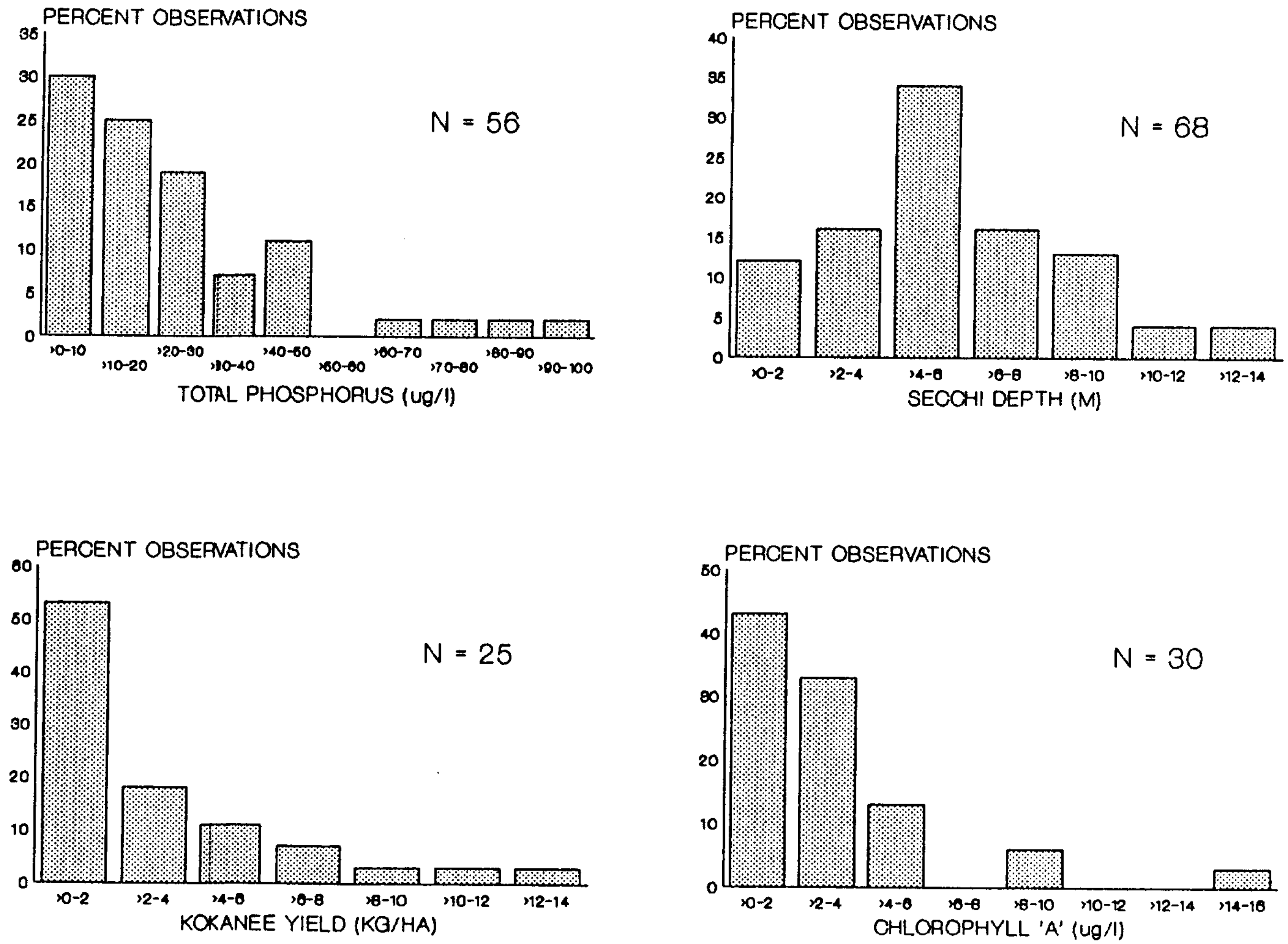

Figure 2. Ranges and distribution of observations for kokanee yield, total phosphorus, Secchi depth, and chlorophyll 'a' for all lakes sampled.

Table 1. Calculations of kokanee yield estimates for 28 lakes and reservoirs in Idaho, Washington, Oregon, Montana, Utah, Colorado and British Columbia.

Body of water	Mean length in catch (mm)	Mean weight in catch[a] (g)	Number harvested	Total weight (kg)	Lake surface area (ha)	Yield (kg/ha)	Comments
Alturas	210	71.85	107	8	339	0,023	1986-87 mean
Anderson Ranch	---	247.00	33,600	8,299	1,918	4,327	1985 only
Coeur d'Alene	215	77.74	521,517	40,544	12,743	3,182	1979-80 mean
Dworshak	258	143.13	206,976	29,624	6,920	4,281	1988 only
Island Park	330	326.25	158	52	3,153	0,016	Winter fishery only
Payette	288	206.84	1,276	264	2,160	0,122	1987-88
Pend Oreille	245	120.38	838,460	100,935	38,348	2,632	1958-62
Priest	---	140.00	84,131	11,778	9,454	1,246	1968-70
Redfish	240	112.35	1,400	157	608	0,259	1968-87
Spirit	245	128.10	59,480	7,619	598	12,741	1981 only
Stanley	194	55.11	150	8	74	0,112	1986
Banks	364	453.02	60,740	27,516	11,008	2,500	7 year mean
Billy Clapp	260	146.88	6,126	900	405	2,222	1978 only
Chelan	285	199.72	6,000	1,198	13,355	0,090	Represents decline
Deer	411	680.24	584	397	445	0,893	1938-40
Loon	387	556.15	584	325	457	0,711	1938-40
Merwin	300	237.13	4,693	1,113	1,619	0,687	1978-82
Sammamish	---	442.00	359	159	1,982	0,080	Represents decline
Yale	305	250.62	10,919	2,737	1,538	1,779	Represents decline
Koocanusa	307	256.17	29,480	7,552	18,160	0,416	1987, BC only
Okanagan	---	174.00	156,000	27,144	35,112	0,773	1971, 1978-80
Flathead	312	270.40	495,910	130,095	51,039	2,627	1981-82
Flaming Gorge		623.00	30,294	18,873	17,000	1,110	1985-88
Porcupine		300.00	1,580	474	80	5,925	1979 only
Dillon	276	179.38	67,575	12,121	1,300	9,324	1975-79
Green Mountain	351	401.09	14,200	5,696	850	6,701	1975-79
Granby	317	285.18	58,000	16,541	2,938	5,630	1975-79
Odell		230.00	64,000	14,720	1,454	10,124	

[a] $W = 0.0000121(L^{3.347517})$

TABT1.3B3

We found a strong positive relationship (r^2 = 0.72) between effort (rod/hours/hectare) and kokanee yield (kg/hectare) (Figure 3). The data also suggest relationships may exist between yield and lake productivity (Table 2). Regression analysis incorporating both effort and a productivity index as independent variables did not provide any significant improvement in single variable models of yield.

When we divided the lakes sampled by elevation (Figure 4), there was a stronger relationship between yield and morphoedaphic index (r = 0.76; P = 0.05) and between yield and chlorophyll 'a' (r = 0.77; P = 0.05) for lakes at elevations --<1,000 m (Table 3). Lakes at elevations >1,000 m exhibited a stronger relationship between yield and total phosphorus (r = 0.93; P = 0.05) and between yield and Secchi (r = 0.50; P = 0.10). Sample sizes for the higher elevation lakes, however, were low (n = 9 and 5, respectively). Measures of productivity for two lakes with kokanee yield estimates at elevations >1,000 m were not available (Figure 1).

DISCUSSION

Many empirical models relating abiotic and biotic factors to total fish yield or standing crop of fish have been developed. MEI is a useful tool for predicting potential fish yield among lakes and reservoirs that have similar growing seasons (Ryder 1965, 1974; Jenkins 1967, 1982; Henderson et al. 1973). Hanson and Leggett (1982) found total phosphorus and macro-benthos biomass/mean depth to be stronger predictors of total fish yield than morphoedaphic index. Oglesby et al. (1987) predicted walleye yield using chlorophyll 'a' concentration as the independent variable.

Lake productivity data that were the most easily obtained for our data set were MEI, total phosphorus, chlorophyll 'a', and mean summer Secchi depth. Measures of macro-benthos biomass are not readily available from normal lake inventory records. Zooplankton biomass, which would be a more logical choice for use in kokanee lakes because of their close association to kokanee, also is not readily available. Therefore, neither macro-benthos or zooplankton biomass were considered in our analysis.

Morphoedaphic Index

MEI was originally described as a quick and convenient method of estimating potential fish yield from large north-temperate lakes at altitudes <600 m (Ryder et al. 1974). Since its first description, MEI has been used as a yield or biomass estimator for lakes and reservoirs belonging to several different systems throughout the world (Ryder et al. 1974; Jenkins 1967). The criteria that Ryder et al. (1974) set up for the identification of lakes suitable for regression of yield on MEI are: 1) similar climatic conditions, 2) similar ionic composition of dissolved material, 3) proportional flushing rates per unit of lake volume,

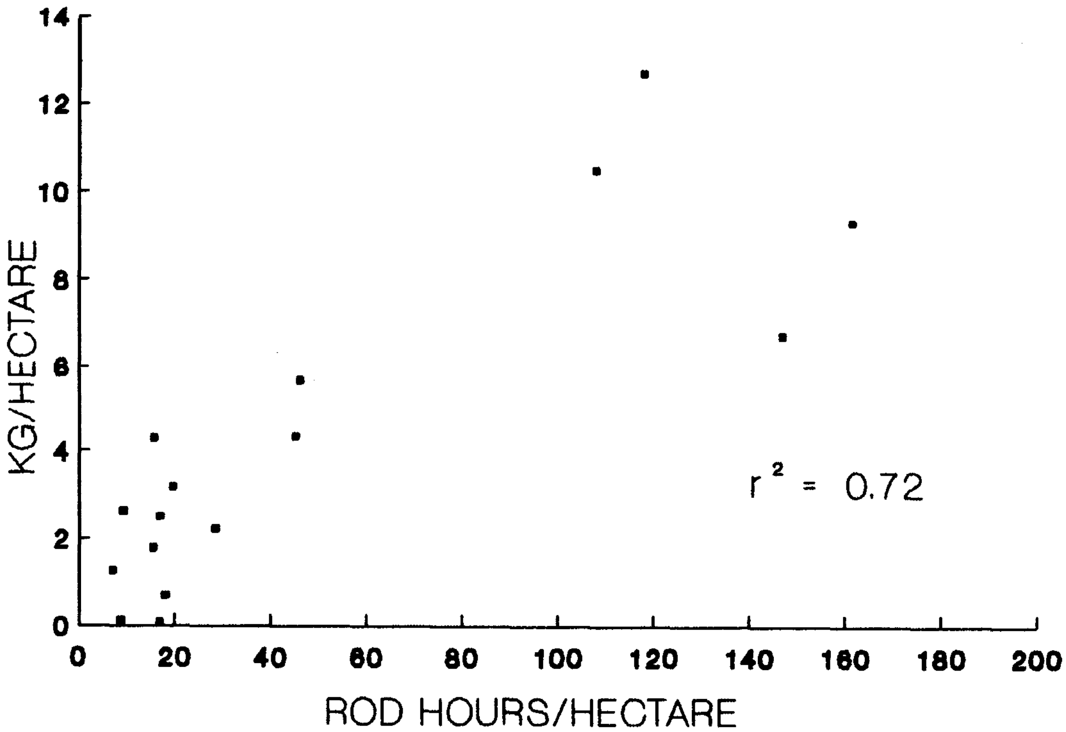

Figure 3. Relationship of effort (rod hours/hectare) to kokanee yield for all lakes sampled.

Table 2. Correlation coefficients for whole data set. Asterisk denotes r values at greater than 95% confidence.

	Yield	Secchi	MEI	Total P	Chlorophyll 'a'	Effort
Yield	1.000					
Secchi Depth	-0.355*	1.000				
MEI	0.178	-0.452*	1.000			
Total Phosphorus	0.140	-0.640*	0.362	1.000		
Chlorophyll 'a'	0.455*	-0.704*	0.699*	0.464*	1.000	
Effort	0.853*	-0.056	0.573*	-0.040	0.526*	1.000

TABT1.JB3

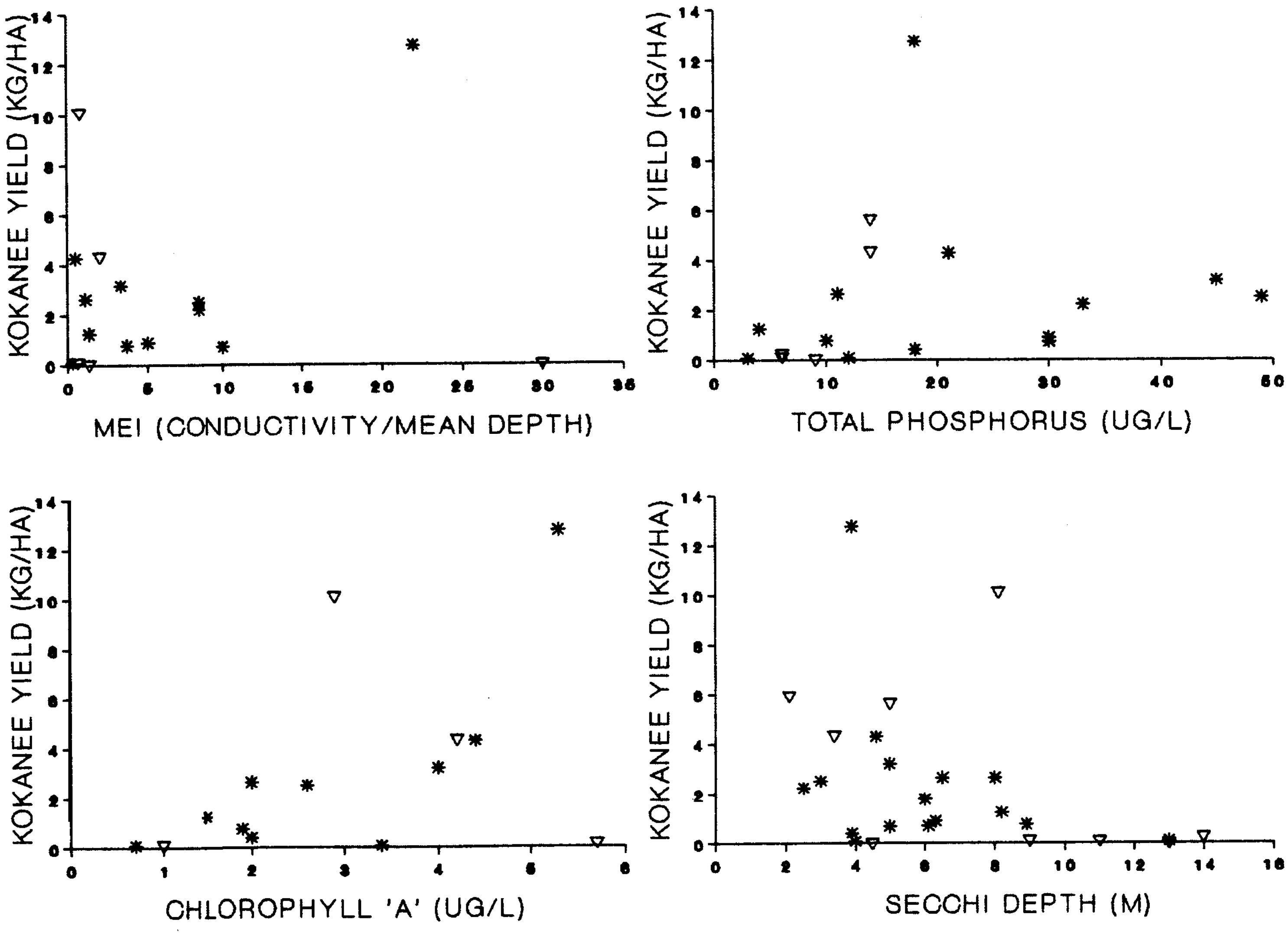

Figure 4. Relationship of 4 productivity indices to kokanee yield for all lakes sampled. Triangles represent lakes at elevations >1000m; asterisk represent lakes at elevations <1000m.

Table 3. Correlation coefficients of four productivity indices with yield using a data set stratified by elevation. Asterisk denotes r values at 95% confidence. Sample size in parentheses.

	Elevation s1000 m	All Observations	Elevation >1000 m
MEI	0.760 (11)	0.178 (16)	0.367 (5)
Total Phosphorus	0.071 (13)	0.140 (18)	0.930 (5)
Secchi Depth	-0.314 (16)	-0.355 (25)	-0.496 (9)
Chlorophyll 'a'	0.767 (10)	0.455 (14)	0.089 (4)

TABT1.JB3

4) inorganic turbidity on the same order of magnitude for all lakes, and 5) moderate to intense fishing effort over several years.

Our data suggest that MEI may be a useful estimator of kokanee yield in lower elevation (<1,000 m) lakes and reservoirs ($r = 0.76$; $P = 0.05$). Correlations of yield with MEI for the entire data set, however, resulted in an r value of only 0.18. This low r value may be caused by a violation of Ryder's criteria for the use of MEI when it is applied to the entire range of our data set. Greater consideration of climate or growing season, and ionic content of the water may lead to more accurate use of MEI as a predictor.

Total Phosphorus

Our data show total phosphorus to be a poor predictor of fish yield in the lower elevation lakes and for the entire data set. Total phosphorus, however, may be useful in higher elevation lakes ($r = 0.93$; $P = 0.01$), although our sample size is very small ($n = 5$).

Because of their position in the watershed, higher elevation lakes may have lower concentrations of suspended sediments and associated phosphorus. If so, more of the phosphorus in these systems would be present in a biologically available form rather than adsorbed to sediment particles. The use of total phosphorus alone as a predictor of potential yield may be inappropriate in situations where a large amount consists of phosphorus that is adsorbed to soil particles (Oglesby 1977). Edmundson and Koenings (1986) found that dissolved phosphorus levels ranged from a low of 9% of the total phosphorus in highly turbid systems (40 NTU) to 56% in lakes with low turbidity (NTU <10). The effect of turbidity on the availability of phosphorus should be incorporated into any model using total phosphorus as an indicator of productivity.

Chlorophyll 'a'

Oglesby et al. (1987) found regression of walleye and total fish yield on mean growing season chlorophyll 'a' concentration indicated strongly positive correlations ($r^2 = 0.81$ and 0.73, respectively). Our data show chlorophyll 'a' may also be useful as **a** yield predictor for low elevation lakes ($r = 0.77$ for lakes at elevations s1,000 m).

Although a strong relationship generally exists between total phosphorus and mean summer chlorophyll 'a' concentrations (Dillon and Rigler 1974; Hoyer and Jones 1983), this relationship may be affected by a number of variables. High flushing rates may remove phytoplankton from the system before they reach their maximum level (Oglesby 1977; Hoyer and Jones 1983). High levels of inorganic suspended solids also may cause significant decreases in chlorophyll 'a' concentrations (Hoyer and Jones 1983; Edmundson and Koenings). The relationship we found between total phosphorus and chlorophyll 'a' concentrations in our data was somewhat lower than that found in the literature ($r^2 = 0.46$), suggesting that flushing rates or inorganic suspended solids may be affecting our data. Flushing rates ranged from 0.02 to 11 years in lakes where yield data were available. Measurements of turbidity were not included in our data set.

Because Chlorophyll 'a' concentrations may reflect the difference between biologically available phosphorus and the measures of total phosphorus, it should prove to be a better overall indicator of potential yield than total phosphorus. Again, because of small sample size, we cannot draw any conclusions.

Mean Summer Secchi Depth

Mean summer Secchi depth was the variable most easily obtained (n = 25). Secchi transparency showed significant inverse relationships with MEI, total phosphorus and chlorophyll 'a', and a relationship with kokanee yield when analyzed using all observations ($r = 0.36$; $P = 0.05$). Kokanee growth is related to lake productivity as expressed by Secchi transparency or chlorophyll 'a' (Job 2 this report). Because Secchi transparency correlates well with other productivity indices and with kokanee growth, it may be a good choice as an overall indicator. A much larger sample size, however, may be needed to describe the relationship to kokanee yield.

Effort

Effort had a strong correlation with kokanee yield and may explain some of the variability in our relationships of yield and productivity. Multiple regressions incorporating both productivity and effort, however, did not prove to be useful. The observations may be too limited in range and number to effectively incorporate both variables.

Summary and Conclusions

We have summarized a substantial amount of information on kokanee fisheries in a form accessable to kokanee biologists. Most observations, however, are incomplete. Complete yield and productivity information are limited to lakes of low or intermediate productivity. Although the data suggest that several relationships may exist between yield and productivity, effort was the most important predictor. Other factors may also be important. Environmental limitations or the presence of predator or competitive species may also affect yield. Given this, the upper limits of our points may best represent the potential of a system. For lakes with yields substantially below the potentials suggested here, managers should examine alternative explanations for poor fishing. Lakes with fishing effort less than 80 rod hours/hectare may be underexploited.

TEXT.JB3

The relationships we found between lake productivity and fish yield show promise for their use in developing a valuable tool for the management of kokanee in Idaho. More useful empirical models will require observations over a wider range of lake productivity. More observations may also allow the incorporation of several independent variables, such as flushing rates, turbidity, and length of growing season.

RECOMMENDATIONS

1) Chlorophyll 'a', Secchi depth, MEI, elevation, and fishing effort were the best potential predictiors of kokanee yield. The use of phosphorous concentrations may be confounded by variation in the biologically available form. Long-term monitoring and inventory of kokanee fisheries should include at least one, and preferably all, of the first four paramaters.

2) Inventory of any new fisheries should incorporate estimates of kokanee yield, total effort, and the parameters discussed in Recommendation 1 whenever possible. The observations summarized in this report are too few or incomplete to incorporate several variables in a predictive model. More complete observations may provide better predictions of potential yield. Additional data available on lakes in Montana and British Columbia should be obtained to expand the data base.

3) The upper limits of yields observed in our lakes should be considered the upper limits of potential yield for lakes of comparable productivity. In the absence of more complete information, the data summarized here can provide a perspective for managers of kokanee fisheries.

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ACKNOWLEDGMENTS

Several people were instrumental in compiling the information for the regional data base. Steve Jackson and Eric Hagen, Washington Department of Wildlife, and Bruce Sheperd and W.T. Westover, British Columbia Ministry of Environment, each contributed substantial amounts of information to the data base. Stan Allen provided consultation on dBase structure and dBase related problems.

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APPENDIX A.

Summary forms used for data collection

TEXT.JB3

LAKE: ....

State or Province ....

LAKE CHARACTERISTICS:

Elevation, (meters above sea level): __________ Latitude: __________

Drainage Basin Area (sq.km): __________ Maximum Depth (m): __________

Lake Surface Area at Full Pool (ha): __________ Mean Depth (m): __________

Shoreline Length (km): __________ Volume: __________

Theoretical Flushing Rate (lake volume/mean annual outflow): ______________

Mean Depth of Thermocline (top of thermocline) in August: ______________

Total Phosphorus at Spring Overturn, Expressed as P (ug/l): ______________

TDS (mg/l): ____________ OR Conductance (umhos/cm^2 at 25°C): __________

(orophyll "a" (ug/l): __________ (mean) __________ (range) ______________ (sampling period for mean, i.e., annual, May-Sept.)

Secchi Depth (m): __________ (mean) __________ (range) ______________ (sampling period for mean, i.e., annual, May-Sept.)

COMMENTS: (include other observations that can help define productivity or trophic status, i.e., C^{14} estimates, oxygen deficits, common algal blooms, winter kill)

MAJOR PERTURBATIONS TO THE SYSTEM:

Physical

Drawdowns (annual range in meters): ________________________

Month(s) largest reduction in lake surface elevation occurs: ______________________

C ENTS: (other major perturbations or problems: dams on tributaries, blocked spawning habitat, entrainment of fish via water release points, or other important changes and relative significance of the problem)

Biological

Mysis (Y/N): ______________ Year Mysis Introduced: __________

Density Range ($\#/m^2$): ______________ Year Obviously Established: __________

COMMENTS: (other biological perturbations, macrophytes (milfoil), other invertebrates (common name), cultural eutrophication, ...)

KOKANEE POPULATION:

Introduced or Native: ______________ Year 1st Introduced ______________

Source lake if introduced (original native stock if known): ______________

Predominant age of spawning fish:

Fish that spawn after the third summer are considered to be age 2+
If split evenly between two ages, i.e. 3 and 4, list as 3.5.

Range: ______________ Dominant: ______________

Peak spawning time (mode of temporal distribution): ______________ month(s)

Length at Age:

Note method of estimate (scale back calculation, otolith, length frequency).
If length does not represent size-at-annulus formation, note the month of sample and place a plus (+) after the age (i.e., during first summer/fall, age = 0+);
Range is for all fish in all years.

Method of Estimate: ______________ Month of Sample: ______________

	Length (mm)		
Age	Mean	Range	Mean of all yrs.
0			
I			
II			
III			
IV			
V+ & older			
Spawners			

COMMENTS: (obvious density dependence, differences in growth between males and females)

Abundance: Population number or density (no/ha). For "Mean of 5 years" give mean of highest 5 consecutive years. If less than 5 consecutive years are available, note the sample size.

Total Number: Range: ______________ Mean of 5 years: ____________

Method of Estimate (trawl, acoustics...): ______________

Total Adult Number (escapement plus harvest of mature fish):

Range: ______________ Mean of 5 years: ____________

Method(s) of Estimates ______________________________

COMMENTS:

Management: Number stocked. For "Mean of 5 years" give mean of highest 5 consecutive years. If less than 5 consecutive years of data are available, note the sample size. For "Time of release" give month targeted for peak release. For "Percent contribution" give the percent of the population from hatchery production in years of maximum hatchery release.

Number stocked annually: Range: ______________ Mean of 5 yrs.: ________

Size at release (mm): Range: ______________ Mean: ____________

Time of release (month): ______________________________

Contribution of hatchery vs. wild (%): ______________________________

COMMENTS: (special management, research, or fishery development programs - include such things as long term monitoring, fertilization, and experimental releases ...)

FISH COMMUNITY

Predators: Species (Common Name): ______________________________

COMMENTS: (estimates of escapement or density, relative importance of predator, relative effect on kokanee...)

Other Fish: List all species (common name): ______________________________

____

____

COMMENTS: (relative abundance, estimates of density, interaction with kokanee...)

(

FISHERY

Total Angler Effort: (Rod hours/year) estimated hours for a full season. For "Mean of 5 years" give mean of highest 5 consecutive years. If less than 5 consecutive years of data are available, note the sample size.

Range: ______________________

Mean of 5 Years: ______________________

COMMENTS: (Note if census does not represent all angler effort or full season - if estimate is in days, provide an estimate of the length of an angler day).

Percent Effort Targeting Kokanee: (What percent of the total estimated effort is by anglers specifically targeting kokanee?) For "Mean of 5 years" give highest 5 consecutive years. If less than 5 consecutive years of data are available, note sample size.

Range: ____________________ Mean of 5 Years: ____________________

COMMENTS:

Catch Rates: (preferably fish per rod hour; if by rod day, provide an estimate of the length of a day)

Summer mean: ________________ Annual mean: ____________________

Primary Method: ____________________________
(trawl, handlines, other)

COMMENTS:

Kokanee Harvest: Total number of fish in the catch of all fishermen for the whole lake. For "Mean of 5 years" give highest 5 consecutive years. If less than 5 consecutive years of data are available, note sample size. For "Mean size in catch" provide the mean weight of fish in catch during the above period.

Range: ______________________________

Mean of 5 Years: ____________________

Mean Size in Catch (g): _______________

COMMENTS: (peak season, methods, causes of variability, long term declines...)

Predator Harvest: Total number of fish in the catch of all fishermen for the whole lake. For "Mean of 5 years" give highest 5 consecutive years. If less than 5 consecutive years of data are available, note sample size. For "Mean size in catch" provide the mean weight of fish in catch during the above 5 years.

Range: ______________________________

Mean of 5 Years: ____________________

Mean Size in Catch (g): ______________

COMMENTS: (peak season, methods; causes of variability, long term declines ...)

REGULATIONS

Seasons: ____

Daily Bag Limits: ____

COMMENTS:

==

KEY REFERENCE(S) FOR THIS LAKE

Person: _____________________________________ phone: _______________

Publication(s) or Report(s): ____

____

____

I RMATION SUMMARIZED BY: ____

APPENDIX B.

Data base structure for Regional.dbf

TEXT.JB3

DATA STRUCTURE FOR DATA8ASE: RESlONAL.DBF

FIELD NAME	FIELD TYPE	FIELD WIDTH	DEC	DESCRIPTION OF DATA	NUMBER OF OBSERVATIONS
....		=~==		....	
WATER	CHARACTER	15		LAKE NAME	74
CODE	CHARACTER	4		LAKE NAME CODE FOR USE IN SYSTAT	
STATE	CHARACTER	2		STATE	74
ELEV	CHARACTER	4		ELEVATION (METERS)	73
LATITUDE	CHARACTER	6		LATITUDE	64
DRAINAGE	CHARACTER	8	1	DRAINAGE BASIN AREA (KM2)	65
SA	CHARACTER	8	1	SURFACE AREA (HA)	74
SHORELINE	CHARACTER	5	1	SHORELINE LENGTH <KM2>	65
MAXDEPTH	CHARACTER	5	l	MAXIMUM DEPTH ((I)	69
MEANDEPTH	CHARACTER	5	1	MEAN DEPTH (M)	72
VOLUME	CHARACTER	8		VOLUME (ACRE FEET)	66
FLUSHRATE	CHARACTER	6	C.	FLUSH RATE (YK)	26
THERMDCLlM	CHARACTER	2		TOP OF THERMOCLINE (M)	42
MEI	CHARACTER	3		MORPHOEDAPHIC INDEX	10
TA	CHARACTER	3		TOTAL PHOSPHORUS (UGXL)	56
CONDUCT	CHARACTER	3		CONDUCTIVITY	56
CHLOR_A	CHARACTER	4	1	CHLOROPHYLL =A= (UGIL)	30
SECCHI	CHARACTER	4	1	SECCHl DEPTH (M)	66
D_DDNN	CHARACTER	5	2	ANNUAL MEAN DRAW DOWN (K)	26
DONN_MOS	CHARACTER	10		MONTH(S) OF DRAWOONN	16
TRl8_DAMS	CHARACTER	1		DAMS ON TRIBUTARIES (Y/N)	19
MYSlS	CHARACTER	1		MYSIS PRESENT (Y/N)	60
MYSIS_H	CHARACTER	4		MYSIS ABUNDANCE (RANGE - HIGH)	
MYSlS1L	CHARACTER	4		MYSlS ABUNDANCE (RANGE - LOW)	
MYSlS_EST	CHARACTER	4		YEAR MYSIS ESTABLISHED	6
KOK_SOUKCE	CHARACTER	15		SOURCE OF KOKAN[[	48
SPANH_MOS	CHARACTER	20		PEAK SPAWNING MONTHS	0
AGE_MATURE	CHARACTER	3	1	AGE AT MATURITY	15
LN 0	CHARACTER	3		MEAN LENGTH AT AGE 0+ (MM)	7
LN_I	CHARACTER	3		MEAN LENGTH AT AGE I+ (MM)	14
LNll	CHARACTER	3		MEAN LENGTH AT AGE lI+ (MM)	25
LN_Ill	CHARACTER	3		MEAN LENGTH AT AGE lll+ (MM)	22
LN_IV	CHARACTER	3		MEAN LENGTH AT AGE IV+ (MM)	12
MONTH	CHARACTER	9		MONTH OF SAMPLE FOR LENGTH AT AGE	17
LN_SPANN	CHARACTER	3		MEAN LENGTH OF SPAWNERS (MM)	7
[SCAP_Hl	CHARACTER	6		ESCAPEMENT TO SPAWN (RANG[- HIGH)	1
ESCAP_LU	CHARACTER	6		ESCAPEMENT TO SPAWN (RANGE - LOW)	1
ESCAP_MEAN	CHARACTER	6		ESCAPEMENT TO SPAWN (MEAN)	1
ESCAP_MTK	CHARACTER	10		METHOD FOR ESTIMATING ESCAPEMENT	
TRIB_SPAWN	CHARACTER :	2		PERCENT TRIBUTARY SPAWNERS	0
STOCK[D_Hl	CHARACTER	7		NUMBER STOCKED PER YEAR (RANGE - HIGH)	20
STDCKED_LU	CHARACTER	7		NUMBER STOCKED PER YEAR (RANGE LOW)	16
STOCKED_X	CHARACTER	7		NUMBER STOCKED PER YEAR (MEAN)	20
ST0CKJlME	CHARACTER	10		MONTH STOCKED	27
HATCHERY_C	CHARACTER	2		PERCENT HATCHERY CONTRIBUTION	
NO_XOKAMEE	CHARACTER	3		MEAN KOKANE[ABUNDANCE (NO/HA)	L~
NO KOK Hl	CHARACTER	4		KOKANEE ABUNDANCE (NO/HA) (RANGE - HIGH	6
NO_KOK_L0	CHARACTER	3		KOKANE[&BUNDANCE (HO/HA) (RANGE - LOW)	6

PREDATORS	MEMO	10		PREDATOR SPECIES	
SPECIES	MEMO	10		SPECIES COMPOSITION	
EFFORT	CHARACTER	6		TOTAL FISHING EFFORT (ROD HOURS)	
EFFOKT_HI	CHARACTER	6		TOTAL FISHING EFFORT (RANGE HIGH) `	7
EFFOFT_LO	CHARACTER			TOTAL FISHING EFFORT (RANGE LOW)	
[FFORT_KOK	CHARACTER	2		PERCENT OF EFFORT TARGETING XOKANEE	
Y{ELD_XOK	CHARACTER	6	3	KOKANEE YIELD (KG/HA)	24
HARVEST_K	CHARACTER	6		MEAN NUMBER' OF KOKANEE HARVESTED	2
HARVEST_Hl	CHARACTER	6		NUMBER OF KOKANEE HARVESTED (RANGE - Hl	7
HARVEST_LO	CHARACTER	6		NUMBER OF KOKANEE HARVESTED (RANGE LO	
KOK_S~ZE	CHARACTER	3		MEAN SIZE OF K0KANEE IN THE CATCH (G)	2 :
P_HARYEST	CHARACTER	6		MEAN NUMBER OF PREDATOR SPECIES HARVEST	rt
P_SlZE	CHARACTER	4		MEAN SIZE OF PREDATOR IN THE CATCH G)	~
YlELD_PRED	CHARACTER	6		PREDATOR YIELD (KG/HA)	4
REG	MEMO	10		REGULATIONS	
REF_NO	CHARACTER	42		CROSS REFERENCE TO INFORMATION SOURCE	74

APPENDIX C.

Summary Report of Lake Characteristics

TEXT.JB3

REGIONAL DATA BASE
LAKE CHARACTERISTICS

BODY OF WATER	ST	LAT	ELEV (M)	DRAIN AREA (KM2)	SURFACE AREA (HA)	SHORE LENGTH (KM)	MAX DEPTH (M)	MEAN DEPTH (M)	VOLUME (ACFT)	FLUSH RATE (YR)	THERMO-CLINE (M)	TOTAL PHOS. (UG/L)	COND	CHLOR "A" (UG/L)	SECCHI DEPTH (M)	DRAW DOWN (M)	MYS Y/N	MEI
** BC																		
KOOCANUSA	BC	490000	741	23491.0	18160.0	360.0	113.0	38.4	4711013	0.670	20	18	230	2.0	3.9	-----	N	---
OKANAGAN	BC	495200	341	6040.0	35112.0	270.0	242.0	76.0	----	---	15	10	280	1.9	8.9	1.00	Y	3.7
** CO																		
DILLON RES.	CO	-----	2750	----	1300.0	---	60.0	23.0	248270	---	--	---	---	----	----	6.00		---
GRANBY	CO	-----	2524	1023.0	2938.0	64.4	61.0	22.6	----	---	10	14	---	----	5.0	28.60	Y	---
GREEN MOUNTAIN	CO	-----	2423	----	850.0	---	---	22.0	154660	---	--	---	---	----	----	18.00		---
SHADOW MOUNTAIN	CO	-----	2551	1023.0	749.0	---	---	3.0	----	---	3	23	---	----	4.3	----		---
** ID																		
ALTURAS	ID	435500	2140	85.0	339.0	8.0	67.0	38.0	77577	---	7	9	49	----	13.0	----		1.3
ANDERSON RANCH	ID	432330	1280	2536.0	1918.0	7.0	67.0	29.8	493000	0.657	6	14	60	4.2	3.4	19.00	N	2.0
COEUR D'ALENE	ID	474000	649	9576.0	12743.0	202.0	61.0	24.0	2479183	0.550	22	45	80	4.0	5.0	2.00	N	3.3
DEADWOOD	ID	441930	1618	290.0	1295.0	17.0	30.0	15.0	160600	0.940	7	30	37	9.9	1.3	----		2.5
DWORSHAK	ID	463000	488	6315.0	6920.0	282.0	192.0	62.0	3468000	0.790	5	21	30	4.4	4.6	47.00		0.5
ISLAND PARK	ID	442400	1920	----	3153.0	80.0	22.0	5.0	127269	0.280	6	---	150	5.7	4.5	----		30.
LUCKY PEAK	ID	433200	933	6547.0	1153.0	66.0	64.0	24.4	228060	0.100	4	---	70	2.5	5.0	----		2.9
MACKAY	ID	435700	1847	1892.0	542.0	12.0	---	10.0	43936	0.490	9	3	219	1.3	4.5	----		21.
PALISADES	ID	431700	1713	13478.0	6515.0	107.0	32.0	26.5	1400000	0.290	12	39	220	1.5	3.5	----	N	8.3
PAYETTE	ID	445730	1524	373.0	2160.0	38.0	95.0	35.0	612840	2.320	5	6	20	1.0	9.0	----	N	0.6
PEND OREILLE	ID	480730	629	59265.0	38348.0	310.0	351.0	164.0	50987714	2.740	15	11	180	2.0	6.5	4.00	Y	1.1
PRIEST LAKE	ID	483100	652	1480.0	9454.0	109.0	112.0	38.0	2912224	3.120	4	4	50	1.5	8.2	1.00	Y	1.3
REDFISH LAKE	ID	440700	1996	103.0	608.0	15.0	89.0	46.0	226718	---	6	6	---	----	14.0	----		---
SPIRIT LAKE	ID	475630	686	125.0	598.0	21.0	27.0	10.9	52853	---	8	18	240	5.3	3.9	----		22
STANLEY	ID	431400	1984	38.0	74.0	4.0	27.0	15.0	9160	---	7	---	---	----	11.0	----		---
UPPER PRIEST	ID	484600	744	1481.0	567.0	14.0	30.0	12.0	55155	---	4	6	100	2.9	6.0	----	Y	8.3
** MT																		
FLATHEAD LAKE	MT	-----	882	18400.0	51039.0	200.0	113.0	32.5	13448210	2.200	10	---	---	----	8.0	3.00	Y	---
** OR																		
ODELL	OR	-----	1459	----	1454.0	---	86.0	41.0	----	---	12	---	32	2.9	8.1	----	N	0.7
** UT																		
FLAMING GORGE	UT	-----	----	----	17000.0	---	---	---	----	---	--	---	---	----	----	----		---
PORCUPINE	UT	-----	1615	91.0	80.0	---	42.4	20.1	----	---	--	---	---	----	2.1	----	N	---
** WA																		
ALDER LAKE	WA	464809	368	740.7	1254.6	45.1	88.4	22.9	230000	---	--	29	40	----	3.0	----	N	1.7
AMERICAN LAKE	WA	470630	72	65.8	445.2	19.3	27.4	16.2	60000	---	7	90	95	----	5.4	----	N	5.9
ANGLE LAKE	WA	472530	111	2.1	40.5	3.5	15.8	7.6	2600	---	--	46	72	----	4.9	----	N	9.4
BAKER LAKE	WA	483858	221	557.0	2017.4	---	---	---	220600	---	--	---	---	----	----	15.20	N	---
BANKS LAKE	WA	473703	479	----	11008.0	131.5	52.0	13.5	1300000	0.480	24	49	112	2.6	3.0	4.60	N	8.3
BILLY CLAPP L.	WA	472654	407	----	405.0	22.5	33.5	19.8	65000	0.020	--	33	165	----	2.5	----	N	8.3
BONAPARTE LAKE	WA	484735	1084	18.1	66.8	9.1	33.6	10.1	5500	---	--	50	225	----	3.7	----	N	22.

REGIONAL DATA BASE
LAKE CHARACTERISTICS

BODY OF WATER	ST	LAT	ELEV (M)	DRAIN AREA (KM2)	SURFACE AREA (HA)	SHORE LENGTH (KM)	MAX DEPTH (M)	MEAN DEPTH (M)	VOLUME (ACFT)	FLUSH RATE (YR)	THERMO-CLINE (M)	TOTAL PHOS. (UG/L)	COND	CHLOR "A" (UG/L)	SECCHI DEPTH (M)	DRAW DOWN (M)	MYS Y/N	MEI
BUMPING LAKE	WA	465200	1045	----	526.0	---	36.8	11.2	47687	0.450	9	73	40	0.8	4.7	6.10	N	3.6
CASCADE LAKE	WA	483850	105	8.9	68.8	5.1	21.3	8.2	4600	---	--	6	180	-----	6.1	-----	N	21.
CAVANAH	WA	481950	307	19.1	323.8	12.2	24.4	13.4	36000	---	8	---	30	-----	4.6	-----	N	2.2
CHAIN LAKE	WA	480305	588	195.3	35.6	8.3	39.7	10.1	2900	---	--	48	523	-----	4.9	-----	N	51.
CHAPMAN LAKE	WA	472123	657	125.6	60.7	9.0	48.8	20.1	9900	---	--	32	240	-----	1.0	-----	N	11.
CHELAN LAKE	WA	475004	339	2393.2	13354.9	175.7	453.0	144.0	15807392	11.000	35	3	50	0.7	13.0	7.00	Y	0.3
CLE ELUM LAKE	WA	471443	678	525.8	1948.0	32.2	101.5	44.5	702816	1.040	12	15	57	0.8	8.8	18.30	N	1.3
CLEAR LAKE	WA	465533	237	1.1	64.7	3.4	25.9	11.6	61000	---	8	9	52	-----	8.3	-----	N	4.5
COOPER LAKE	WA	472516	850	72.3	52.6	5.0	15.0	6.4	2600	---	--	5	15	-----	9.2	-----	N	2.3
DAVIS LAKE	WA	481352	664	46.1	60.1	4.3	45.8	25.3	13000	---	--	17	85	-----	3.1	-----	N	3.6
DEEP LAKE-GRANT	WA	473518	376	9.0	44.0	8.8	36.6	22.3	7800	---	--	---	290	-----	11.6	-----	N	13.
DEEP LAKE-KING	WA	-----	235	10.2	15.0	2.1	22.6	10.1	1200	---	--	15	62	-----	4.6	-----	N	6.1
DEER LAKE	WA	480628	755	47.1	445.2	22.3	22.9	15.9	57000	5.940	13	30	79	-----	6.3	-----	N	5.0
EASTON LAKE	WA	471429	665	486.9	97.1	6.5	12.2	5.2	4000	---	--	5	40	-----	4.9	-----	N	7.7
KACHEES LAKE	WA	471553	687	165.5	1516.0	62.2	131.3	66.4	818616	3.890	14	11	47	0.5	8.5	7.30	N	0.7
KEECHELUS LAKE	WA	471920	768	141.7	1039.0	24.0	98.7	37.4	313973	1.400	8	33	44	2.0	6.8	16.40	N	1.2
LOON LAKE	WA	480320	726	36.7	457.3	20.5	30.5	14.0	51500	---	10	30	148	-----	6.1	-----	N	10.
LOST LAKE	WA	471953	924	7.7	68.8	5.0	51.9	21.7	12000	---	--	3	20	-----	10.4	-----	N	0.9
MERIDIAN LAKE	WA	472130	113	2.6	60.7	4.0	27.4	12.4	648	---	--	70	78	3.2	4.1	-----	N	6.3
MERWIN LAKE	WA	455726	73	1890.7	1618.8	51.5	57.9	30.5	404552	0.120	9	---	---	-----	5.0	3.00	N	---
MOUNTAIN LAKE	WA	483901	278	5.9	72.8	6.8	42.7	14.9	8800	---	--	8	105	-----	7.0	-----	N	7.0
PADDEN LAKE	WA	484215	136	6.8	64.7	3.7	18.0	8.2	4300	---	10	8	78	-----	6.1	0.73	N	9.5
PALMER LAKE	WA	485439	349	766.6	849.9	25.7	24.1	15.6	110000	---	--	20	250	-----	2.3	-----	N	16.
PIERRE LAKE	WA	485351	611	69.4	44.5	4.7	22.9	8.5	3000	---	6	94	343	9.2	4.2	-----	N	40.
PIPE-LUCERNE	WA	472158	167	1.3	22.3	2.7	19.8	8.2	1500	---	5	20	49	-----	3.2	-----	N	6.0
RIMROCK LAKE	WA	463800	890	----	1025.0	---	53.6	23.8	198000	0.530	--	43	68	1.5	1.5	17.40	N	2.8
ROESIGER SO.ARM	WA	475819	174	9.2	56.7	4.8	21.3	6.7	3000	---	--	24	---	2.9	4.3	0.40	N	---
ROESIGER-NO.ARM	WA	475917	174	5.0	80.9	4.6	33.5	14.6	9600	---	--	28	26	2.3	5.6	0.40	N	---
SAMMAMISH LAKE	WA	473500	8	253.0	1982.0	39.8	31.0	17.7	283722	0.600	10	21	---	3.4	4.0	1.00	N	---
SAWYER LAKE	WA	472003	156	33.7	121.4	11.3	17.7	7.9	7700	---	--	17	139	-----	4.3	-----	N	17.
SHANNON LAKE	WA	483253	133	769.2	930.8	35.4	79.2	28.3	210000	---	--	10	35	-----	-----	-----	N	1.2
STAR LAKE	WA	472110	97	1.5	14.2	1.8	15.2	7.6	870	---	--	---	84	-----	6.7	-----	N	11.
STEILACOOM LAKE	WA	471040	64	231.5	129.5	9.2	6.1	3.4	3500	---	2	30	108	-----	2.1	-----	N	31.
STEVENS LAKE	WA	480053	64	17.7	42.1	11.1	46.0	20.5	68442	3.380	10	20	115	15.0	4.4	1.25	N	5.6
SULLIVAN LAKE	WA	485022	789	132.6	566.6	14.3	100.7	58.0	270000	---	--	21	75	-----	5.6	-----	N	1.3
TOAD LAKE	WA	484723	217	1.3	13.4	1.9	9.4	6.1	660	---	--	13	88	-----	2.7	-----	N	14.
TROUT LAKE	WA	480702	673	122.5	38.9	2.9	54.9	13.1	4200	---	--	---	---	-----	3.1	-----	N	---
WASHINGTON LAKE	WA	474000	4	1564.0	8959.0	115.0	65.0	33.0	2350843	---	--	---	---	-----	-----	-----	N	---
WENATCHEE LAKE	WA	474831	570	707.1	10911.7	20.9	73.2	45.8	360000	---	--	5	18	-----	6.1	-----	N	0.3
WILDERNESS LAKE	WA	-----	143	1.7	27.9	2.9	11.6	6.4	1420	---	3	---	70	2.7	3.7	0.40	N	10.
YALE LAKE	WA	455753	149	1543.6	1537.5	41.8	76.2	33.5	402000	0.140	4	---	---	-----	6.0	7.00	N	---

APPENDIX D.

Summary Report of Kokanee Population Characteristics

REGIONAL DATA BASE
KOKANEE POPULATION

BODY OF WATER	KOKANEE SOURCE	DENSITY LOW (NO/HA)	DENSITY HIGH (NO/HA)	DENSITY MEAN (NO/HA)	MEAN LN AGE 0+ (MM)	MEAN LN AGE I+ (MM)	MEAN LN AGE II+ (MM)	MEAN LN AGE III+ (MM)	MEAN LN SPAWNER (MM)	AGE AT MATURITY	ESCAPEMENT TO SPAWN (MEAN)	TIME OF SPAWNING
** BC												
KOOCANUSA		---	---	---	---	---	---	---	---	---	----	
OKANAGAN		---	---	399	57	129	209	234	---	---	----	
** CO												
DILLON RES.		---	---	---	---	---	---	---	300	4.0	----	
GRANBY		---	---	---	---	---	---	---	293	---	----	
GREEN MOUNTAIN		---	---	---	---	---	---	---	---	---	----	
SHADOW MOUNTAIN		---	---	---	---	---	---	---	---	---	----	
** ID												
ALTURAS		---	---	---	---	---	---	---	---	---	----	
ANDERSON RANCH	INTROD/UNKNOWN	218	848	442	57	160	225	320	---	4.0	7000	SEPT
COEUR D'ALENE	PEND OREILLE	473	1355	938	---	146	187	227	242	4.0	----	NOV/DEC
DEADWOOD		---	---	---	---	---	---	---	---	4.0	----	AUG/SEPT
DWORSHAK	WHATCOM/A.RANCH	109	109	109	50	180	240	290	316	4.0	----	
ISLAND PARK		---	---	---	---	---	---	---	---	---	----	
LUCKY PEAK		---	---	---	---	---	---	---	---	---	----	
MACKAY		---	---	---	---	---	---	---	---	---	----	
PALISADES		---	---	---	---	---	---	---	---	---	----	
PAYETTE	NATIVE/PEND'OR	55	104	82	---	145	205	255	---	4.0	----	AUG/SEPT
PEND OREILLE		189	452	255	---	145	212	242	---	4.5	----	NOV/DEC
PRIEST LAKE		4	50	26	---	154	229	287	---	4.5	----	OCT/DEC
REDFISH LAKE		---	---	---	---	---	---	---	---	---	----	
SPIRIT LAKE		496	1465	983	45	166	211	248	---	---	----	NOV/DEC
STANLEY		---	---	---	---	---	---	---	---	---	----	
UPPER PRIEST		28	169	79	---	133	210	280	---	---	----	OCT/DEC
** MT												
FLATHEAD LAKE	INTRO./UNKNOWN	16	25	19	99	231	299	321	356	4.0	----	OCT/DEC
** OR												
ODELL	KOOTENAY/FLATHD	36	124	88	47	151	220	320	327	4.0	----	OCT/NOV
** UT												
FLAMING GORGE		---	---	---	---	---	---	---	---	---	----	
PORCUPINE	INTRO.	---	---	---	---	124	257	364	---	3.0	----	SEPT.
** WA												
ALDER LAKE		---	---	---	---	---	---	---	---	---	----	
AMERICAN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
ANGLE LAKE	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
BAKER LAKE	NATIVE	---	---	---	---	---	---	---	---	---	----	
BANKS LAKE	NATIVE/WHATCOM	---	---	---	---	---	302	400	---	4.0	----	OCT/NOV
BILLY CLAPP L.	NATIVE/WHATCOM	---	---	---	---	135	226	273	---	4.0	----	OCT/NOV
BONAPARTE LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	

REGIONAL DATA BASE
KOKANEE POPULATION

BODY OF WATER	KOKANEE SOURCE	DENSITY LOW (NO/HA)	DENSITY HIGH (NO/HA)	DENSITY MEAN (NO/HA)	MEAN LN AGE 0+ (MM)	MEAN LN AGE I+ (MM)	MEAN LN AGE II+ (MM)	MEAN LN AGE III+ (MM)	MEAN LN SPAWNER (MM)	AGE AT MATURITY	ESCAPEMENT TO SPAWN (MEAN)	TIME OF SPAWNING
BUMPING LAKE	NATIVE/WHATCOM	---	---	---	---	---	133	144	---	---	----	
CASCADE LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
CAVANAH	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
CHAIN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
CHAPMAN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
CHELAN LAKE	WHATCOM/KOOTENA	---	---	---	---	---	292	320	---	4.5	----	SEPT/OCT
CLE ELUM LAKE	NATIVE/WHATCOM	---	---	---	---	---	---	---	---	---	----	
CLEAR LAKE		---	---	---	113	214	310	---	---	3.0	----	
COOPER LAKE	NATIVE/WHATCOM	---	---	---	---	---	---	---	---	---	----	
DAVIS LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
DEEP LAKE-GRANT	WHATCOM	---	---	---	---	---	---	---	---	---	----	
DEEP LAKE-KING	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
DEER LAKE	WHATCOM	---	---	---	---	---	302	400	---	---	----	
EASTON LAKE		---	---	---	---	---	---	---	---	---	----	
KACHEES LAKE	NATIVE/WHATCOM	---	---	---	---	---	---	---	---	---	----	
KEECHELUS LAKE	NATIVE/WHATCOM	---	---	---	---	---	---	---	---	---	----	
LOON LAKE	WHATCOM	---	---	---	---	---	218	228	---	---	----	
LOST LAKE	WHATCOM	---	---	---	---	---	133	171	---	---	----	
MERIDIAN LAKE	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
MERWIN LAKE	INTRO./UNKNOWN	---	---	---	---	---	380	---	---	3.0	----	SEPT/OCT
MOUNTAIN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
PADDEN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
PALMER LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
PIERRE LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
PIPE-LUCERNE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
RIMROCK LAKE	WHATCOM	281	310	295	---	---	171	207	---	3.0	----	SEPT
ROESIGER SO.ARM	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
ROESIGER-NO.ARM	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
SAMMAMISH LAKE		---	---	---	---	---	219	370	---	---	----	
SAWYER LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
SHANNON LAKE		---	---	---	---	---	---	---	---	---	----	
STAR LAKE	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
STEILACOOM LAKE	INTRO./UNKNOWN	---	---	---	---	---	---	---	---	---	----	
STEVENS LAKE	WHATCOM	---	---	---	---	---	230	287	258	2.5	----	NOV-JAN
SULLIVAN LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
TOAD LAKE	INTRO/UNKNOWN	---	---	---	---	---	---	---	---	---	----	
TROUT LAKE	WHATCOM	---	---	---	---	---	---	---	---	---	----	
WASHINGTON LAKE		---	---	---	---	---	---	---	---	---	----	
WENATCHEE LAKE	NATIVE/WHATCOM	---	---	---	---	---	---	---	---	---	----	
WILDERNESS LAKE		---	---	---	---	---	---	---	---	---	----	
YALE LAKE	CULTAS LAKE ?	---	---	---	---	---	320	---	---	2.0	----	SEPT/OCT

APPENDIX E.

Summary Report of Kokanee Fisheries

Page No. 1
01/03/80

REGIONAL DATA BASE
FISHERY

BODY OF WATER	TOTAL EFFORT (HRS)	KOKANEE EFFORT (%)	KOKANEE HARVEST (LOW)	KOKANEE HARVEST (HIGH)	KOKANEE HARVEST (MEAN)	MEAN SIZE KOKANEE (GRAMS)	KOKANEE YIELD (KG/HA)	PREDATOR HARVEST (MEAN)	MEAN SIZE PREDATOR (GRAMS)	PREDATOR YIELD (KG/HA)
** BC										
KOOCANUSA	----	--	----	----	29480	256	0.416	----	----	----
OKANAGAN	----	--	----	----	156000	174	0.773	----	----	----
** CO										
DILLON RES.	210000	--	----	----	67575	---	----	----	----	----
GRANBY	135631	--	----	----	58000	---	----	1126	830	0.320
GREEN MOUNTAIN	125000	--	----	----	14200	---	----	522	320	0.200
SHADOW MOUNTAIN	----	--	----	----	----	---	----	----	----	----
** ID										
ALTURAS	----	--	----	----	107	71	0.023	----	----	----
ANDERSON RANCH	86553	86	----	----	33600	247	4.327	13900	----	----
COEUR D'ALENE	250036	93	238903	578034	521517	215	3.182	350	8200	2.300
DEADWOOD	----	--	----	----	----	---	----	----	----	----
DWORSHAK	108696	61	32000	207000	206976	143	4.281	----	----	----
ISLAND PARK	----	--	----	----	158	326	0.016	----	----	----
LUCKY PEAK	----	--	----	----	----	---	----	----	----	----
MACKAY	----	--	----	----	----	---	----	----	----	----
PALISADES	----	--	----	----	----	---	----	----	----	----
PAYETTE	18855	--	----	----	1276	206	0.122	----	----	----
PEND OREILLE	355514	--	----	----	838460	120	2.632	----	----	----
PRIEST LAKE	68186	--	----	----	84131	140	1.246	----	----	----
REDFISH LAKE	----	--	----	----	1400	112	0.259	----	----	----
SPIRIT LAKE	70573	--	----	----	59480	128	12.741	----	----	----
STANLEY	----	--	----	----	150	55	0.112	----	----	----
UPPER PRIEST	----	--	----	----	----	---	----	----	----	----
** MT										
FLATHEAD LAKE	----	--	----	----	495910	270	2.627	12399	----	----
** OR										
ODELL	157000	--	11600	89300	64000	230	10.500	----	----	----
** UT										
FLAMING GORGE	----	--	737	38816	30294	623	1.110	10536	2388	1.410
PORCUPINE	----	--	----	----	1580	299	6.000	----	----	----
** WA										
ALDER LAKE	----	--	----	----	----	---	----	----	----	----
AMERICAN LAKE	140500	--	14970	64299	32914	---	----	16394	----	----
ANGLE LAKE	----	--	----	----	----	---	----	----	----	----
BAKER LAKE	----	--	----	----	----	---	----	----	----	----
BANKS LAKE	186363	86	17630	75035	60740	453	2.500	4827	----	----
BILLY CLAPP L.	11509	90	----	----	6126	260	2.222	160	----	----
BONAPARTE LAKE	----	--	----	----	----	---	----	----	----	----

REGIONAL DATA BASE
FISHERY

BODY OF WATER	TOTAL EFFORT (HRS)	KOKANEE EFFORT (%)	KOKANEE HARVEST (LOW)	KOKANEE HARVEST (HIGH)	KOKANEE HARVEST (MEAN)	MEAN SIZE KOKANEE (GRAMS)	KOKANEE YIELD (KG/HA)	PREDATOR HARVEST (MEAN)	MEAN SIZE PREDATOR (GRAMS)	PREDATOR YIELD (KG/HA)
BUMPING LAKE	----	80	----	----	----	---	----	----	----	----
CASCADE LAKE	----	--	----	----	----	---	----	----	----	----
CAVANAH	----	--	----	----	----	---	----	----	----	----
CHAIN LAKE	----	--	----	----	----	---	----	----	----	----
CHAPMAN LAKE	----	--	----	----	----	---	----	----	----	----
CHELAN LAKE	----	--	----	----	6000	199	0.090	65	----	----
CLE ELUM LAKE	----	--	----	----	----	---	----	----	----	----
CLEAR LAKE	----	--	----	----	----	---	----	----	----	----
COOPER LAKE	----	--	----	----	----	---	----	----	----	----
DAVIS LAKE	----	--	----	----	----	---	----	----	----	----
DEEP LAKE-GRANT	----	--	----	----	----	---	----	----	----	----
DEEP LAKE-KING	----	--	----	----	----	---	----	----	----	----
DEER LAKE	----	--	----	----	584	680	0.893	1428	----	----
EASTON LAKE	----	--	----	----	----	---	----	----	----	----
KACHEES LAKE	----	--	----	----	----	---	----	----	----	----
KEECHELUS LAKE	----	--	----	----	----	---	----	----	----	----
LOON LAKE	----	--	----	----	584	556	0.711	118	----	----
LOST LAKE	----	--	----	----	----	---	----	----	----	----
MERIDIAN LAKE	----	--	----	----	----	---	----	----	----	----
MERWIN LAKE	29222	51	----	----	4693	237	0.687	----	----	----
MOUNTAIN LAKE	----	--	----	----	----	---	----	----	----	----
PADDEN LAKE	----	--	----	----	----	---	----	----	----	----
PALMER LAKE	----	--	----	----	----	---	----	----	----	----
PIERRE LAKE	----	--	----	----	----	---	----	----	----	----
PIPE-LUCERNE	----	--	----	----	----	---	----	----	----	----
RIMROCK LAKE	----	95	----	----	----	---	----	----	----	----
ROESIGER SO.ARM	----	--	----	----	----	---	----	----	----	----
ROESIGER-NO.ARM	----	--	----	----	----	---	----	----	----	----
SAMMAMISH LAKE	33400	--	----	----	359	442	0.080	----	----	----
SAWYER LAKE	----	--	----	----	----	---	----	----	----	----
SHANNON LAKE	----	--	----	----	----	---	----	----	----	----
STAR LAKE	----	--	----	----	----	---	----	----	----	----
STEILACOOM LAKE	----	--	----	----	----	---	----	----	----	----
STEVENS LAKE	----	--	----	----	----	---	----	----	----	----
SULLIVAN LAKE	----	--	----	----	----	---	----	----	----	----
TOAD LAKE	----	--	----	----	----	---	----	----	----	----
TROUT LAKE	----	--	----	----	----	---	----	----	----	----
WASHINGTON LAKE	----	--	----	----	----	---	----	----	----	----
WENATCHEE LAKE	----	--	----	----	----	---	----	----	----	----
WILDERNESS LAKE	----	--	----	----	----	---	----	----	----	----
YALE LAKE	23819	72	3398	19346	10919	250	1.779	33	----	----

APPENDIX F.

Species Composition List for Kokanee Lakes and Reservoirs

SPECIES COMPOSITION: SPECIES CODE LIST

ACAL	CHISELMOUTH
ACTR	STURGEON, WHITE
ALSA	SHAD, AMERICAN
CAAR	SUCKER, UTAH
CAAU2	GOLDFISH
CACO	SUCKER, LONSNOSE
CADI	SUCKER, BRIDGELIP
CAMA2	SUCKER, LARSESCALE
CAPL	SUCKER, MOUNTAIN
COBA	SCULPIN, MOTTLED
COCL	SCULPIN, PIUTE
CDCO4	WHITEFISH, LAKE
COEX	SCULPIN, SHORTHEAD
COGR	SCULPIN, SLIMY
COLE	SCULPIN, WOOD RIVER
CDPL	CHUB, LAKE
CORH	SCULPIN, TORRENT
CYCA	CARP
ESLU	PIKE, NORTHERN
GAAF	MOSDUITOFISH
GIAT	CHUB,UTAH
GIBI	CHUB, TUI
GICO	CHUB, LEATHERSIDE
ICME	BULLHEAD, BLACK
1CNE	BULLHEAD, BROWN
ICPU	CATFISH, CHANNEL
ICTA	BULLHEAD--UNKNOWN SP.
LAIR	LAMPREY, PACIFIC
LECY	SUNFISH, GREEN
LEGI	PUMPKINSEED
LEGU	WARMOUTH
LENA	BLUEGILL
LOLO	BURBOT
MIAN	LOACH, JAPANESE WEATHER
MIDO	BASS, SMALLMOUTH
MISA	BASS, LARGEMOUTH
MYCA2	PEAMOUTH
NOGY	MADTOM, TADPOLE
ONKE	SALMON, CHUM
ONKI	SALMON, COHO
ONNE	KOKANEE
ONNE2	SALMON, SOCKEYE
ONT5	CHINOOK
OSMO	SMELT, RAINBOW
PEFL	PERCH, YELLOW
PETR2	ROLLER, SAND
PIPR	MINNOW, FATHEAD
PORN	CRAPPIE, WHITE
PDMO	CRAPPIE--UNKNOWN SP.
PONI2	CRAPPIE, BLACK
PORE	GUPPY
PRAB	WHITEFISH, BEAR LAKE
PRCO	WHITEFISH, PYGMY
PRGE	CISCO, BONNEVILLE
PROS	WHITEFISH--UNKNOWN SP.
PRSP	WHITEFISH, BONNEVILLE
PRWI	WHITEFISH, MOUNTAIN
PTOR	SOUAWFISH, NORTHERN
PYOL	CATFISH, FLATHEAD
RHCA	DACE, LONGNOSE
RHFA	DACE, LEOPARD
RHIN	DACE--UNKNOWN SP.
RHOS	DACE, SPECKLED
RIBA	SHINER, REDSIDE
SAAG	TROUT, GOLDEN
5ARL	CHAR, ARCTIC
SACL	TROUT, CUTTHROAT
SACL2	CUTTHROAT, SNAKE RIVER FINE-SPOTTED
SACL3	TROUT, BEAR LAKE CUTTHROAT
SACLB	TROUT, YELLOWSTONE CUTTHROAT
SACLL	TROUT, WESTSLOPE CUTTHROAT
SACLU	TROUT, BONNEVILLE CUTTHROAT
SACO	TROUT, BULL
SAFO	TROUT, BROOK
SAGA	TROUT, RAINBOW
SAGA2	STEELHEAD
SAGA3	TROUT, GERARD RAINBOW
SANA	TROUT, LAKE
SASA2	SALMON, ATLANTIC
SASP	TROUT, REDBAND
5RTR	TROUT, BROWN
STVI	WALLEYE
THAR	GRAYLING, A M C
TITI	TENCH

REGIONAL DATA BASE
SPECIES COMPOSITION

BODY OF WATER	ONKI	ONNE2	ONTS	SAGA	SATR	SAFO	SACO	SANA	PTOR	LOLO	COT	ACTR	COCL	PRCO	PRWI	SACL	SAGA2	CAAU2	GIAT	COPL	MYCA2
** BC																					
KOOCANUSA				X		X	X	X	X	X	X	X			X	X					X
OKANAGAN				X					X		X		X	X	X						X
** CO																					
DILLON RES.					X	X															
GRANBY				X	X	X		X			X					X					
GREEN MOUNTAIN								X													
SHADOW MOUNTAIN																					
** ID																					
ALTURAS				X		X	X				X				X	X					
ANDERSON RANCH	X		X	X			X		X						X						
COEUR D'ALENE			X													X					
DEADWOOD				X			X								X	X					
DWORSHAK				X		X	X		X		X				X	X					
ISLAND PARK																					
ISLAND PARK																					
LUCKY PEAK																					
MACKAY																					
PALISADES					X			X							X	X			X		
PAYETTE				X				X													
PEND OREILLE				X			X						X			X					
PRIEST LAKE				X		X	X	X	X		X			X	X	X					X
REDFISH LAKE																					
SPIRIT LAKE				X		X										X					
STANLEY						X	X	X								X					
UPPER PRIEST																					
** MT																					
FLATHEAD LAKE																					
** OR																					
ODELL				X			X	X							X						
** WA																					
ALDER LAKE																					
AMERICAN LAKE				X							X				X	X					
ANGLE LAKE				X																	
BAKER LAKE	X	X	X	X	X		X	X			X					X					
BANKS LAKE			X	X	X				X	X	X		X		X						X
BILLY CLAPP L.			X	X					X	X	X		X		X						X
BONAPARTE LAKE				X		X		X													
BUMPING LAKE				X		X	X								X	X					
CASCADE LAKE				X							X					X					
CAVANAH				X												X					
CHAIN LAKE						X															

REGIONAL DATA BASE
SPECIES COMPOSITION

BODY OF WATER	ONKI	ONNE2	ONTS	SAGA	SATR	SAFO	SACO	SANA	PTOR	LOLO	COT	ACTR	COCL	PRCO	PRWI	SACL	SAGA2	CAAU2	GIAT	COPL	MYCA2
CHAPMAN LAKE				X																	
CHELAN LAKE			X	X				X	X	X	X				X	X				X	X
CLE ELUM LAKE				X		X	X	X	X	X	X			X	X	X					
CLEAR LAKE				X												X					
COOPER LAKE				X	X	X										X					
DAVIS LAKE				X																	
DEEP LAKE-GRANT				X				X			X							X			
DEEP LAKE-KING				X												X					
DEER LAKE				X	X	X		X													
EASTON LAKE				X			X														
KACHEES LAKE				X			X		X	X				X	X	X					
KEECHELUS LAKE				X			X		X	X	X			X	X	X					
LOON LAKE				X	X			X													
LOST LAKE						X															
MERIDIAN LAKE	X			X																	
MERWIN LAKE	X		X	X			X		X		X					X					
MOUNTAIN LAKE				X												X					
PADDEN LAKE				X												X					
PALMER LAKE				X						X					X	X					
PIERRE LAKE				X		X										X					
PIPE-LUCERNE				X																	
RIMROCK LAKE				X		X	X								X	X					
ROESIGER SO.ARM																					
ROESIGER-NO.ARM																					
SAMMAMISH LAKE	X	X	X	X					X		X					X					X
SAWYER LAKE				X												X					
SHANNON LAKE																					
STAR LAKE				X																	
STEILACOOM LAKE																					
STEVENS LAKE	X			X												X					
SULLIVAN LAKE				X	X		X									X					
TOAD LAKE				X																	
TROUT LAKE				X																	
WASHINGTON LAKE	X	X	X	X			X		X		X	X			X	X	X				X
WENATCHEE LAKE		X		X			X		X		X					X					
WILDERNESS LAKE																					
YALE LAKE				X		X	X		X		X				X	X					

REGIONAL DATA BASE
SPECIES COMPOSITION

BODY OF WATER	PTOR	RHCA	RHOS	RIBA	TITI	CAAR	CACAS	CACO	CAMA2	CAPL	ICNE	LECY	LEGI	LEMA	MIDO	MISA	PONI2	PEFL	STVI	STBK	LATR
** BC																					
KOOCANUSA	X	X		X			X		X				X			X		X			
OKANAGAN	X			X			X		X			X						X			
** CO																					
DILLON RES.																					
GRANBY							X														
GREEN MOUNTAIN																					
SHADOW MOUNTAIN																					
** ID																					
ALTURAS																					
ANDERSON RANCH	X			X				X	X						X			X			
COEUR D'ALENE											X					X	X	X			
DEADWOOD																					
DWORSHAK	X	X	X	X				X	X		X				X	X	X				X
ISLAND PARK																					
ISLAND PARK																					
LUCKY PEAK																					
MACKAY																					
PALISADES				X		X															
PAYETTE																		X			
PEND OREILLE																					
PRIEST LAKE	X	X		X				X	X			X				X					
REDFISH LAKE																					
SPIRIT LAKE																X					
STANLEY				X																	
UPPER PRIEST																					
** MT																					
FLATHEAD LAKE																					
** OR																					
ODELL																					
** WA																					
ALDER LAKE																					
AMERICAN LAKE											X		X		X	X	X	X		X	
ANGLE LAKE																X		X			
BAKER LAKE																					
BANKS LAKE	X						X		X				X		X	X	X	X	X		
BILLY CLAPP L.	X						X		X				X		X	X	X	X	X		
BONAPARTE LAKE																					
BUMPING LAKE									X												
CASCADE LAKE																				X	
CAVANAH																					
CHAIN LAKE																					

REGIONAL DATA BASE
SPECIES COMPOSITION

BODY OF WATER	PTOR	RHCA	RHOS	RIBA	TITI	CAAR	CACA5	CACO	CAMA2	CAPL	ICNE	LECY	LEGI	LEMA	MIDO	MISA	PONI2	PEFL	STVI	STBK	LATR
CHAPMAN LAKE															X	X	X				
CHELAN LAKE	X							X	X												
CLE ELUM LAKE	X			X					X												
CLEAR LAKE																		X			
COOPER LAKE																					
DAVIS LAKE																					
DEEP LAKE-GRANT											X										
DEEP LAKE-KING											X						X	X			
DEER LAKE					X						X		X	X	X	X	X	X			
EASTON LAKE		X	X																		
KACHEES LAKE	X			X					X												
KEECHELUS LAKE	X			X					X												
LOON LAKE					X						X		X	X	X	X	X	X			
LOST LAKE																					
MERIDIAN LAKE											X					X	X	X			
MERWIN LAKE	X								X												
MOUNTAIN LAKE																				X	
PADDEN LAKE																X					
PALMER LAKE															X						
PIERRE LAKE																	X				
PIPE-LUCERNE											X							X			
RIMROCK LAKE									X												
ROESIGER SO.ARM																					
ROESIGER-NO.ARM																					
SAMMAMISH LAKE	X								X		X		X		X	X	X	X		X	
SAWYER LAKE											X		X			X		X			
SHANNON LAKE																					
STAR LAKE											X										
STEILACOOM LAKE																					
STEVENS LAKE															X	X	X	X			
SULLIVAN LAKE																					
TOAD LAKE																					
TROUT LAKE												X			X	X					
WASHINGTON LAKE	X		X	X					X							X	X	X		X	X
WENATCHEE LAKE	X						X	X	X												
WILDERNESS LAKE																					
YALE LAKE	X								X												

APPENDIX G.

Sources of Information

Regional Data Base
Sources of Information

REF NO.	SOURCE	YEAR	PUBLICATION	AGENCY
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2	Bowler, B.	1975	Lake Pend Oreille kokanee life history studies, Job Performance Report, Project F-53-R-11, Job IV-E	Idaho Department of Fish and Game, Boise
3	Bowler, B.	1976	Lake Pend Oreille kokanee life history studies, Job Performance Report, Project No. F-53-R-11, Job IV-E	Idaho Department of Fish and Game, Boise
4	Bowler, B.	1979	Kokanee life history studies in Priest Lake. Lake and Reservoir Investigations, Job Performance Report, Project No. F-73-R-2, Study V, Job III	Idaho Department of Fish and Game, Boise
5	Bowler, B.	1980	Kokanee life history studies in Pend Oreille Lake. Lake and Reservoir Investigations, Job Performance Report, Project No. F-73-R-2	Idaho Department of Fish and Game, Boise
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8	Brown, Larry			(509) 663-9711
9	Bull, C.J.	1987	Okanagan lake plan	Okanagan sub-region technical report
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13	Cochnauer, T.	1984	Enhancement of kokanee in Priest and Pend Oreille Lakes, Job Performance Report, Project No. F-73-R-6, Study VI, Job IV	Idaho Department of Fish and Game, Boise
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15	Cummins, J.	1984	Rimrock resident fishery	(509) 753-5713
16	Cropp,Tom			Washington Department of Fish and Wildlife (206) 840-0540
17	Eddy, B., and P. Meyers.	1985	Evaluation of the contribution of coho to the 1984 Merwin Reservoir sport fishery.	Pacific Power and Light Company, Portland, Oregon. (503) 464-4221
18	Ellis, V.L., B. Rieman, and T. Cochnauer	1982	Kokanee lake systems inventory - Spirit Lake. Lake and Reservoir Investigations, Job Performance Repoirt, Project No. F-73-R-4	Idaho Department of Fish and Game, Boise
19	Ellis, V.L., and B. Bowler	1980	Pend Oreille Lake creel census. Lake and Reservoir Investigations, Job Performance Report, Project No. F-73-R-2, Job I	Idaho Department of Fish and Game, Boise
20	Ellis, V.L., and B. Bowler	1979	Pend Oreille Lake creel census. Lake and Reservoir Investigations, Job Performance Report, Project No. F-72-R-1	Idaho Department of Fish and Game, Boise
21	Graves, S.K.	1984	Merwin, Yale, and Swift Reservoir study 1978-1979. Progress Report, Reservoir Fisheries	
22	Hanzel, D.A.	1984	Lake fisheries inventory - annual trends in recruitment and migration of kokanee populations and major factors affecting trends. Job Completion Report	Montana Department of Fish, Wildlife, and Parks, Kalispell
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REF NO.	SOURCE	YEAR	PUBLICATION	AGENCY
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27	Hista, John			(509) 456-4085
28	Irizarry, R.A., and V.L. Ellis	1975	Lake Pend Oreille creel census. lake and Reservoir Investigations, Job Performance Report, Project No. F-53-R-10, Job IV-a	Idaho Department of Fish and Game, Boise
29	Jackson, Steve			(206) 586-7075
30	Janssen, J.P.	1983	Investigation of selected aspects of kokanee (oncorhynchys nerka) ecology in Porcupine Reservoir, Utah, with management implications. Masters Thesis	Utah State University, Logan
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32	Kraemer, Curt			(206)775-1311
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35	LaBolle, L.D., and N.J. Horner	1986	Region 1 lowland lakes investigations. Regional Fishery Management Investigations, Job Performance Report, Project No. F-71-R-12, Job I-b	Idaho Department of Fish and Game, Boise
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Sources of Information

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40	Lucas, Bob			(206) 423-9341
41	Maiole, M.A.	1988	Dworshak Dam impacts assessment and fishery investigation, BPA Project No. 87-99, Contract No. DE-AI79-87BP35167	U.S. Department of Energy, Portland, Oregon
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44	Milligan, J.H., R.A. Lyman, C.M. Falter, E.E. Krumpe, and J.E. Carlson	1983	Classification of Idaho's freshwater lakes.	Idaho Water and Energy Resources Research Institute, University of Idaho
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48	Pfeifer, Bob			Washington Department of Game. (206) 753-5713

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Sources of Information

REF NO.	SOURCE	YEAR	PUBLICATION	AGENCY
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50	Rieman, B.E.	1977	Lake Pend Oreille limnological studies. Lake and Reservoir Investigations, Job Performance Report, Project No. F-73-R-1, Job II	Idaho Department of Fish and Game, Boise. (208) 939-6709
51	Rieman, B.E.	1979	Priest Lake limnology. Lake and Reservoir Investigations, Job Performance Report, Project No. F-73-R-1, Job II	Idaho Department of Fish and Game, Boise. (208) 939-6709
52	Rieman, B., and C.M. Falter	1975	Lake Pend Oreille limnological studies, Lake and Reservoir Investigations, Job Performance Report, Project No. F-53-R-10, Job IV-d	Idaho Department of Fish and Game, Boise. (208) 939-6709
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56	Scholz, A., K. O'Laughlin, T. Peone, J. Uehara, T. Kleist, and J. Hisata	1988	Environmental factors affecting kokanee salmon, oncorhynchus nerka (Walbaum) in Deer and Loon Lakes, Stevens County, Washington	
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58	Sealing, C., and G. Bennett	1980	Middle Park Reservoir studies. Final Report. Federal Aid Project F-40-D	Colorado Division of Wildlife, Grand Junction
59	Stephenson, J. D., and D.P. Zajac	1974	American Lake Fisheries Investigations	DFAE, Forestry Section, Fort Lewis, Washington
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